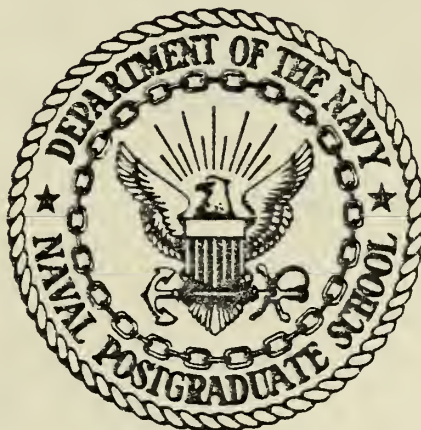


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THESIS

MASS, SALT, AND HEAT TRANSPORT ACROSS FOUR LATITUDE
CIRCLES IN THE SOUTH ATLANTIC OCEAN

By

J. Robert Mason

December 1978

Thesis Advisor:

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The resulting meridional heat transport was then examined and compared with other estimates. Northward (equatorward) heat transports resulted at each latitude, which would seem to oppose the conventional view of the role of the ocean in the earth's heat budget as a means to transfer heat from equator to poles. However, the northward direction of the net absolute heat transport agrees with the consensus of previous work and is attributed to the warmer surface currents with a net northward transport dominating the cooler deeper currents and their net southward flow.

A general circulation pattern was developed from mass transport values for each of three layers of water: Upper, Intermediate, and Deep and Bottom Water. These derived circulation patterns are then compared to general descriptive circulation patterns found in the literature. General agreement was found with the notable exception of lacking a strong Brazil current in the surface and central waters. Vertical cross sections of velocity, mass, salt, and heat transport were contoured to examine the eddy field circulation pattern and further describe general circulation patterns.

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Mass, Salt, and Heat Transport Across Four Latitude
Circles in the South Atlantic Ocean

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

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I. INTRODUCTION

For the total earth-atmosphere system, the amount of heat received from the sun at the upper boundary of the system must, in the long term average, equal closely the amount of heat lost by reflection and radiation to space. This approximate balance must exist, since observed short term changes in the mean annual temperature of the atmosphere and oceans are small enough to be neglected. Therefore, over a time period of several years, an energy balance may be assumed and the short wave radiation absorbed by the land, the oceans, and the atmosphere is considered balanced by the long wave radiation to space from the entire system. Part of the arriving energy is transformed into the kinetic energy which drives ocean and atmosphere circulations.

The arriving short wave radiation does not strike the earth uniformly. Due to the geometry of the earth's orbit, the lower latitudes receive more short wave energy than is lost by long wave radiation; at higher latitudes the reverse is true. There is consequently a net gain of heat in the tropics and a net loss in the higher latitudes. Since, for a given latitude the mean annual temperatures remain unchanged, there must be energy transport from lower to higher latitudes. The air-ocean circulation systems are primarily responsible for this redistribution of energy between the latitudes.

In the early part of this century it was popularly assumed that the transport of heat by oceanic currents was small or negligible when compared with that transported by the atmosphere. Bjerknes et al. (1936) and Sverdrup et al. (1942) proceeded under this assumption, but provided

the caveat that the question had not been thoroughly examined.

In examining the question further, Jung, in 1952, proposed that the oceans could indeed provide a significant contribution to the heat balance of the earth. Previous works considered only the horizontal surface current systems in heat transport studies whereas Jung proposed closed vertical circulations in the north-south direction which could transport significantly large amounts of heat between equator and pole. Jung's hypothesis was extended in a 1955 study of geostrophic currents in the North Atlantic derived from the METEOR Expedition data which resulted in computations of significant oceanic heat transport meridionally. Other studies have verified further the importance of ocean circulations in the transport of energy. Budyko (1956), Sverdrup (1957), Bryan (1962), Sellers (1965), Emig (1967), Vander Haar and Oort (1973), and Bennett (1978) all estimated significant meridional heat transports in various oceans.

This study attempts a nearly synoptic look at four latitudinal sections in the South Atlantic Ocean between 8°S and 32°S using temperature and salinity data from the International Geophysical Year (1957-1958) and 1959. A computer program developed by Greeson (1974) is used to calculate volume, mass, salt, and heat transports across the various latitude sections. The computer program was modified to include previously hand calculated transports in areas below the deepest sounding and to identify water masses by salinity and temperature criteria. By requiring mass and salt continuity across each section conclusions were drawn concerning the level of no motion, general geostrophic circulation, and net heat flux characteristics of the South Atlantic Ocean during this period.

II. BACKGROUND

A. ENERGY TRANSPORT

The redistribution of energy in the earth-atmosphere system is accomplished primarily by advection of sensible heat within the ocean's current systems and transport of latent and sensible heat within atmospheric circulations. Ordinarily, the processes of conduction throughout continental land masses and through the ocean floor are ignored. Whether the ocean or the atmosphere is the dominant mechanism for energy transport has been a source of debate over the past century.

Maury (1856) and Ferrel (1890) maintained that the ocean was the chief source of energy transport meridionally because even though oceanic velocities are an order of magnitude smaller than atmospheric velocities and the atmosphere has a greater volume exchange than the ocean, the mass exchange and heat capacity of the ocean is greater. An opposing view was held by Bjerknes et al. (1933) and Sverdrup et al. (1942), both of whom assumed that the transport of energy from lower to higher latitudes by ocean currents is negligible when compared to the atmospheric contribution for worldwide averages, but can be of importance locally in certain regions. A study by Angstrom (1925) indicated a rough equality between ocean and atmospheric contributions to energy transport. Jung (1952, 1955) showed that meridional transport by the oceans, while not as large as the atmosphere, was not insignificant. Neumann et al. (1966) stresses the importance of the ocean, particularly in transferring energy to the region between 20°N and 40°N wherein it is made available to the atmosphere in the form of latent heat for further northward transport.

This study attempts a quantitative analysis of the ocean transports of mass, salt, and heat across vertical cross sections of the ocean in the South Atlantic Ocean at four latitudes.

B. DETERMINATION OF THE LEVEL OF NO MOTION

The procedure for computing transports in this study uses the dynamic method for calculating relative geostrophic velocities between oceanographic station pairs. The procedure is described in Section IV-B. In order to obtain quantitative estimates of the transports, however, the relative geostrophic velocities calculated by the dynamic method must be converted to absolute velocities. To accomplish this, a level of no meridional motion was required against which the relative velocities were referenced and thereby converted to absolute velocities.

Since current measurements are not taken along with the standard oceanographic station cast, indirect methods of determining the level of no motion have been developed over the past 60 years. A comprehensive summary of these methods is found in Sherfesse (1978) and Baker (1978) and includes descriptions of techniques developed by Jacobsen (1916), Parr (1938), Hidaka (1949), Defant (1941), Sverdrup et al. (1942), Stommel (1956), and Stommel and Schott (1977).

The method used to determine the level of no motion in this study was that from Sverdrup et al. (1942). The method entails imposing the requirement of mass and salt continuity across a given latitude section that extends completely across an ocean basin. The level of no motion is placed at the depth where the transport above the reference level is equal to and opposite to the transport below the reference level. This method requires data across an entire cross section of the ocean and

from the surface to the near bottom. This method proved to be the most reasonable for the comprehensive data used herein.

III. STATEMENT OF THE PROBLEM

The objectives of this study were sixfold: (1) to add to an existing computer program, which computes ocean transports through a vertical cross section, a subroutine which automatically classifies the water masses and sums their transport contributions by individual water mass type; (2) to modify the computer program to include in the transport calculations the cross sectional areas below the deepest sounding adjacent to the bottom whose effects previously were hand calculated; (3) to determine quantitatively the level of no motion in the South Atlantic such that the net mass and salt transport across each of the four sections is approximately zero; (4) to use the resulting mass transport to compare and describe the general circulation of the South Atlantic for Upper, Intermediate, and Deep and Bottom Water layers; (5) to compute the transport of sensible heat from the selected vertical cross sections, and (6) to estimate eddy activity by examining eddy patterns revealed in vertical cross sections of velocity and mass, salt, and heat transport which were contoured by the computer.

IV. PROCEDURE

A. DATA SOURCE

To apply the classic method of determining dynamic depths in the ocean, detailed temperature and salinity observations at known geometric depths below the actual sea surface were required for a given time period. In practice, simultaneous observations are not available, especially for an area the size of the South Atlantic Ocean, but it may be assumed that time changes in the pressure distribution are so small that observations taken within a given time frame may be considered synoptic. This is the assumption most often made in studies of broad oceanic circulations, especially prior to the satellite era.

The most comprehensive set of data meeting these criteria was found in Atlantic Ocean Atlas published by F. C. Fuglister in 1960. It is a compendium of data taken as part of International Geophysical Year (IGY, 1957-1958). To obtain these data, the classic oceanographic station measurements were carried out involving serial observations from surface to near bottom using Nansen bottles and reversing thermometers for temperature and salinity information. Data for the South Atlantic are in transects at four latitudes extending from South America to Africa with stations at roughly one degree intervals. The data were collected between March 1957 and June 1959. Table I shows additional information on these latitudinal cross sections.

Figure 1 shows the tracks along which the data were taken. Although the data were collected over slightly more than a two-year time period, they are considered synoptic for the purpose of studying the general circulation patterns.

TABLE I
OCEANOGRAPHIC STATION DATA

<u>Average Latitude</u>	<u>Vessel</u>	<u>Station Numbers</u>	<u>Dates</u>	<u>Tracks</u>
8°15' S	Crawford	86-92 94-120	March 1-22, 1957	Brazil to Angola
15°45' S	Crawford	121-153	April 1-22, 1957	Brazil to Angola
24°15' S	Crawford	416-458	October 2-26, 1958	Brazil to Southwest Africa
32°30' S	Atlantis	5798 5806-5843	April 11, 1959 April 26 - June 3, 1959	Brazil to Union of South Africa

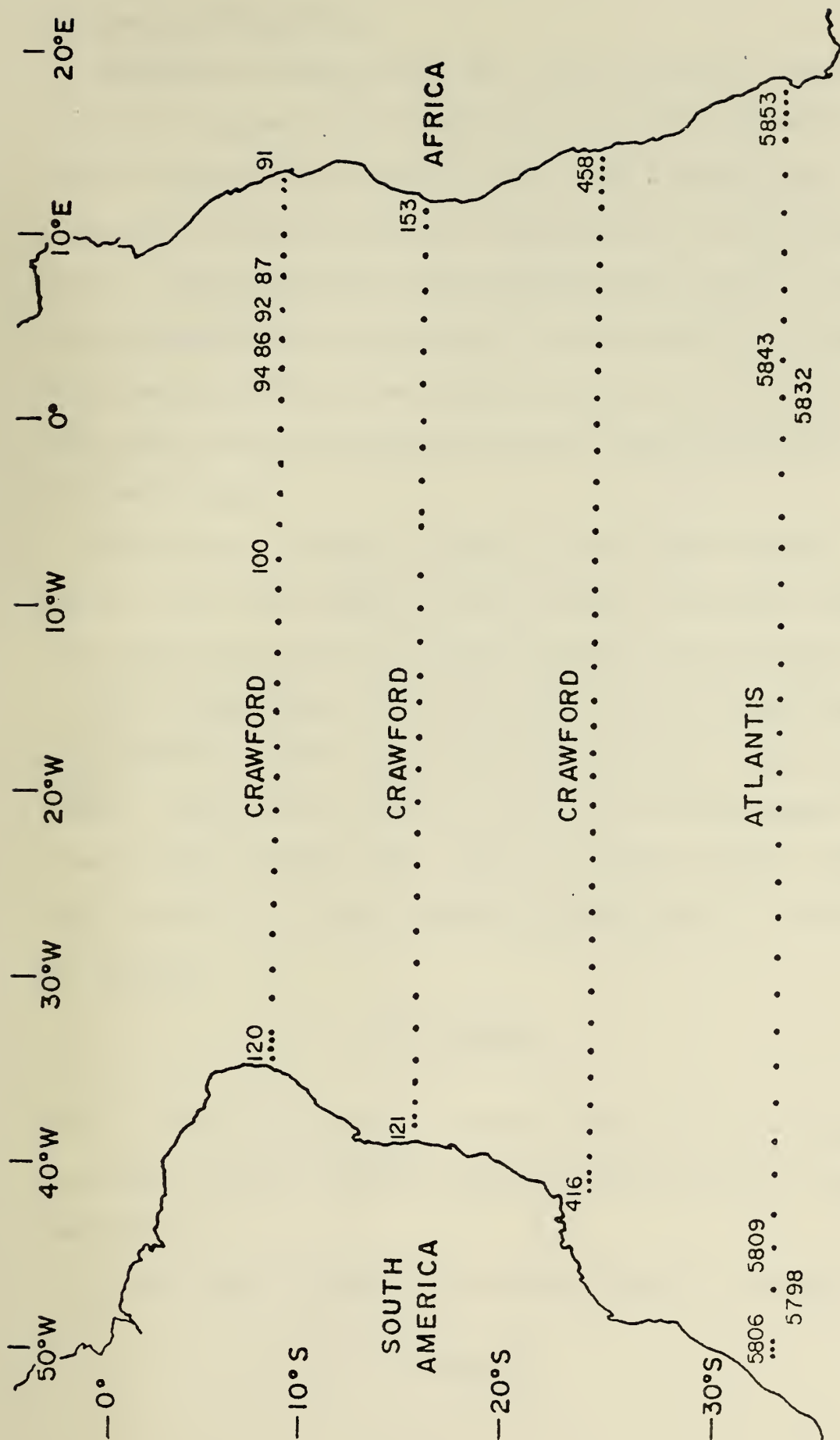


Figure 1. Chart of the Tracks and Station Numbers for Research Vessels Crawford and Atlantis during March 1957-June 1959.

B. COMPUTING TRANSPORTS

Transports of volume, mass, salt, and heat across a vertical cross section were computed using velocities derived by the Helland-Hansen formula [equation (4)] and the procedure from Sverdrup et al. (1942). In general, the method consists of application of the geostrophic approximation. Since the vertical shear of geostrophic velocity is proportional to the horizontal density gradient, a relative velocity profile may be calculated by assuming or measuring a velocity at one level and then vertically integrating measured horizontal density gradients converted to dynamic heights.

Specifically, a computer program was used from a master's thesis by Greeson (1974) which computed dynamic heights for standard depths at each ocean station by the Sverdrup procedure in the following manner.

The IGY temperature and salinity data taken at various depths were interpolated to standard depths using a combination linear and parabolic scheme. Then specific volume and the specific volume anomaly were computed for each standard depth. Next, an average specific volume anomaly for the center of the layer between standard depths is calculated using the equation:

$$\bar{\delta} = \frac{\delta_z + \delta_{(z+\Delta z)}}{2} , \quad (1)$$

where $\bar{\delta}$ is the average specific volume anomaly, and δ_z and $\delta_{(z+\Delta z)}$ are the computed specific volume anomalies at standard depths z and $z+\Delta z$ respectively.

Dynamic height difference, ΔD , for each layer is computed by:

$$\Delta D = \bar{\delta} [z - (z + \Delta z)] . \quad (2)$$

A vertical summation is made to obtain the total dynamic height of each station relative to the sea surface:

$$\sum_0^z \Delta D = D . \quad (3)$$

Next, another subroutine is employed to compute L, the distance between each station pair as a function of latitude and longitude.

Geostrophic relative velocity differences at a location midway between each station pair were calculated for each standard depth using the Helland-Hansen equation:

$$v_1 - v_2 = \frac{10}{fL} (D_A - D_B) \quad (4)$$

where v_1 and v_2 are the velocities at standard depths 1 and 2, D_A and D_B are the dynamic heights of the two stations, and f is the coriolis parameter.

The ocean surface was considered a geopotentially level surface with zero inclination between the pressure surface and the level surface for the purpose of calculating these relative velocities.

In order to convert from relative to absolute velocities, some criterion was required by which to establish the actual surface which has zero inclination, and thus, zero velocity. This surface is the level of no motion discussed in Section II. The method used in this study to determine that depth was simply to impose the requirement that the resulting net mass transport and net salt transport across the entire latitude sections of ocean be zero when based on the selected reference level:

$$\int \rho_s v_n do = 0$$

$$\int \rho_s S v_n do = 0$$
(5)

where S is salinity in parts per thousand and v_n is the velocity component perpendicular to the cross section.

The procedure followed was experimentally to vary the depth of the level of no motion in the computer program until the total net mass and salt balances across the sections were as small as could be obtained. The velocities for the remaining standard depths computed relative to this level of no motion were then considered absolute. The velocities thus obtained apply to a point midway between each station for each standard depth.

From these absolute velocities, transports of volume, mass, salt, and heat for the cross sectional area between the station pairs were next calculated for each layer between the standard depths. The velocities were available at the midpoints between the stations; values of density, salinity and temperature were interpolated for each standard depth.

To obtain a value for velocity, density, salinity, and temperature representative of the entire cross sectional area of the layer between the two stations an averaging process was performed to arrive at a central value for each parameter. The averaging process used by the computer program is illustrated in Figure 2.

These central values and the cross sectional area of the layer are used to compute the transports. The product of area, velocity, and density gives mass transport, which is then multiplied by the salinity and temperature, respectively, to obtain heat transport and salt transport.

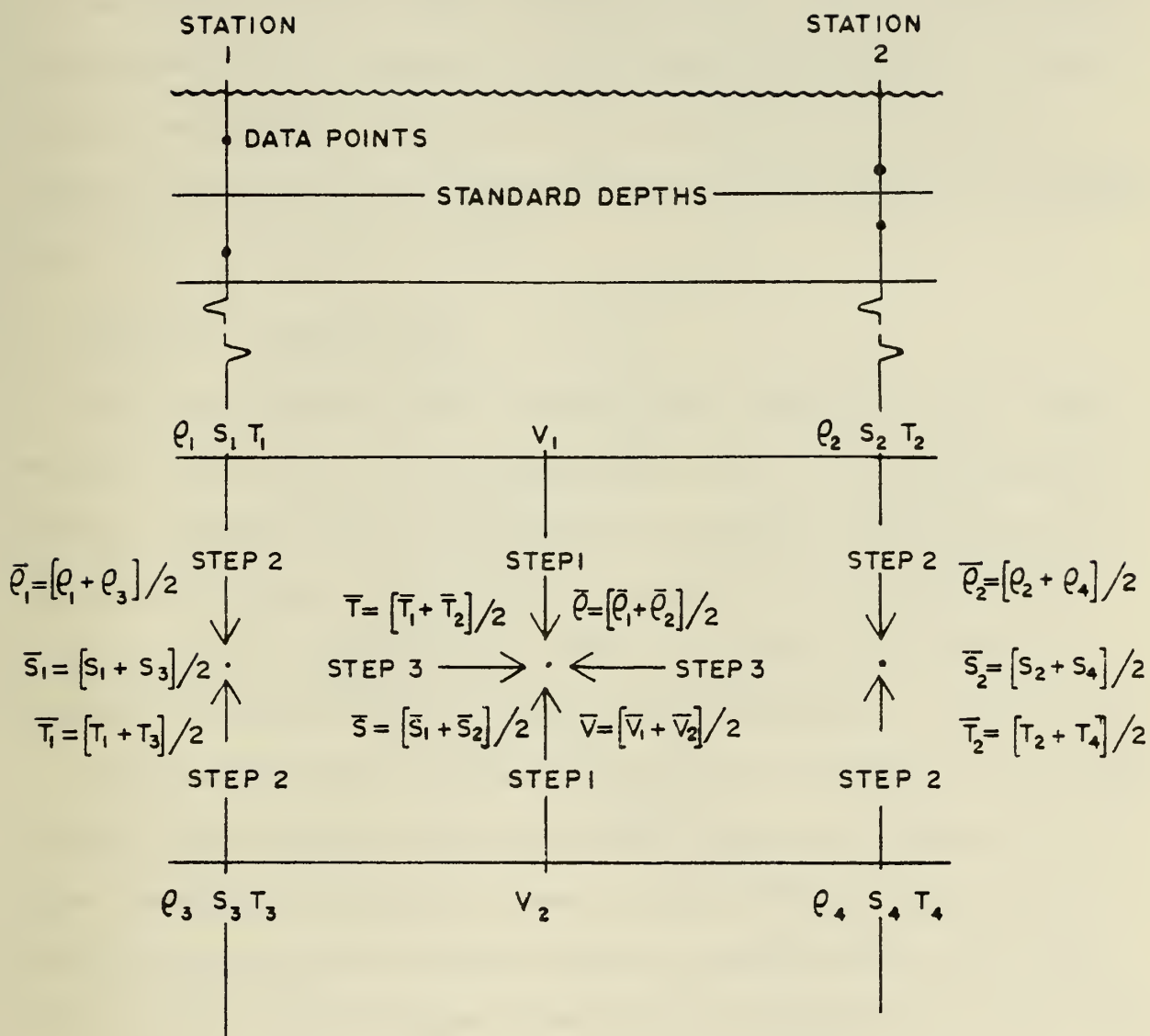


Figure 2. Illustration of the averaging process used to obtain a central mean value for velocity, density, salinity, and temperature for the rectangular cross-sectional area.

Mass, salt, and heat transports are summed in the vertical for each station pair and also in the horizontal for each layer.

Due to the procedures for data interpolation techniques and limitations in the accuracy of the computer, it was impossible to obtain exact zero mass and salt fluxes simultaneously for a single level of no motion. For the purposes of this study, mass balance was considered the primary criterion and salt an important, although secondary, balance consideration for continuity. Once mass and salt continuity was achieved as closely as possible, for the entire section, the corresponding heat transport for the section was recorded.

C. BOTTOM AREA CONTRIBUTIONS

The method described above determines the transports for the cross-sectional area down to the greatest common depths for each station pair. Figures 3 through 6 show the area below the greatest common depths which also must be included. In addition, an estimate must be made for the peripheral areas between the last station on either end of the section and land. An estimate for the latter will be discussed in Section IV-D.

The existing computer program was modified to account for the effects of these areas adjacent to the bottom which in the past were hand calculated. Bathymetric profiles for each latitude section were provided by Woods Hole Oceanographic Institution and the cross-sectional area between the ocean floor and the deepest common depth was measured for each station pair (the near-bottom area). Next, a linear decrease in velocity was assumed from the deepest common level to a zero velocity at the ocean floor; that is, a value of one-half the deepest calculated absolute velocity was used as the average velocity value for each area. Mass transport across the near-bottom area was found by multiplying this velocity by the

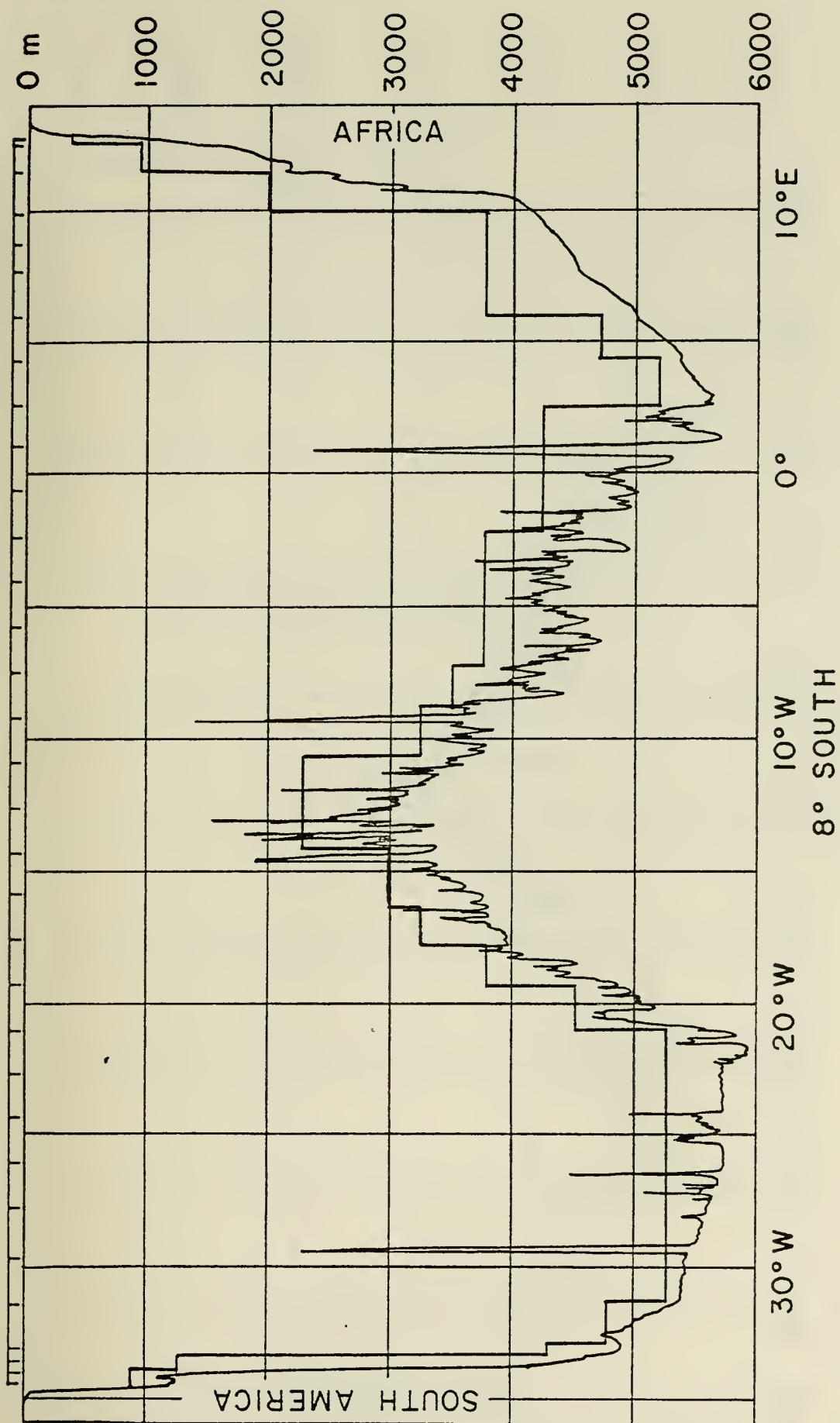


Figure 3. Bottom Peripheral Areas: 8°S Latitude Section.

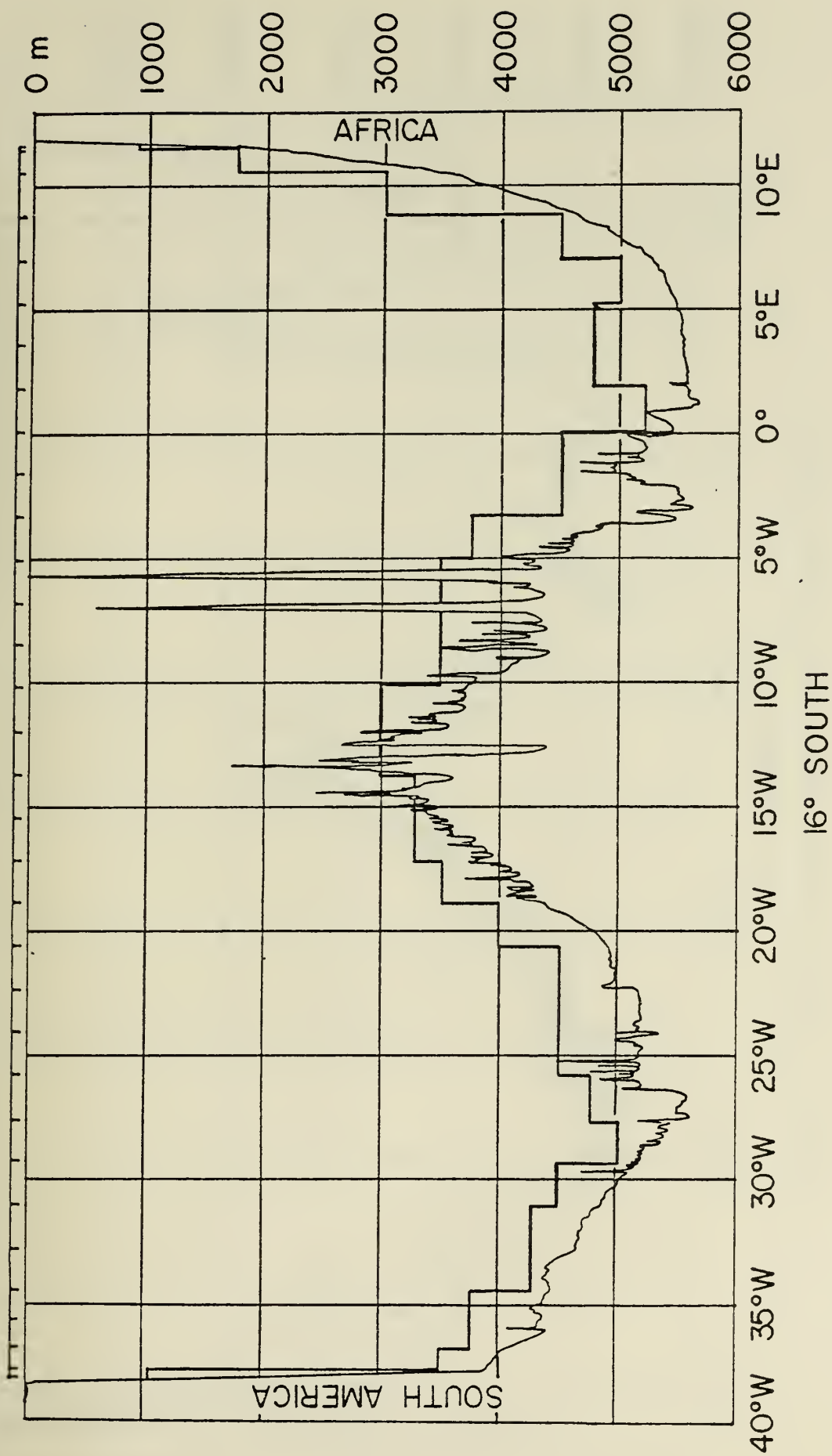


Figure 4. Bottom Peripheral Areas: 16°S Latitude Section.

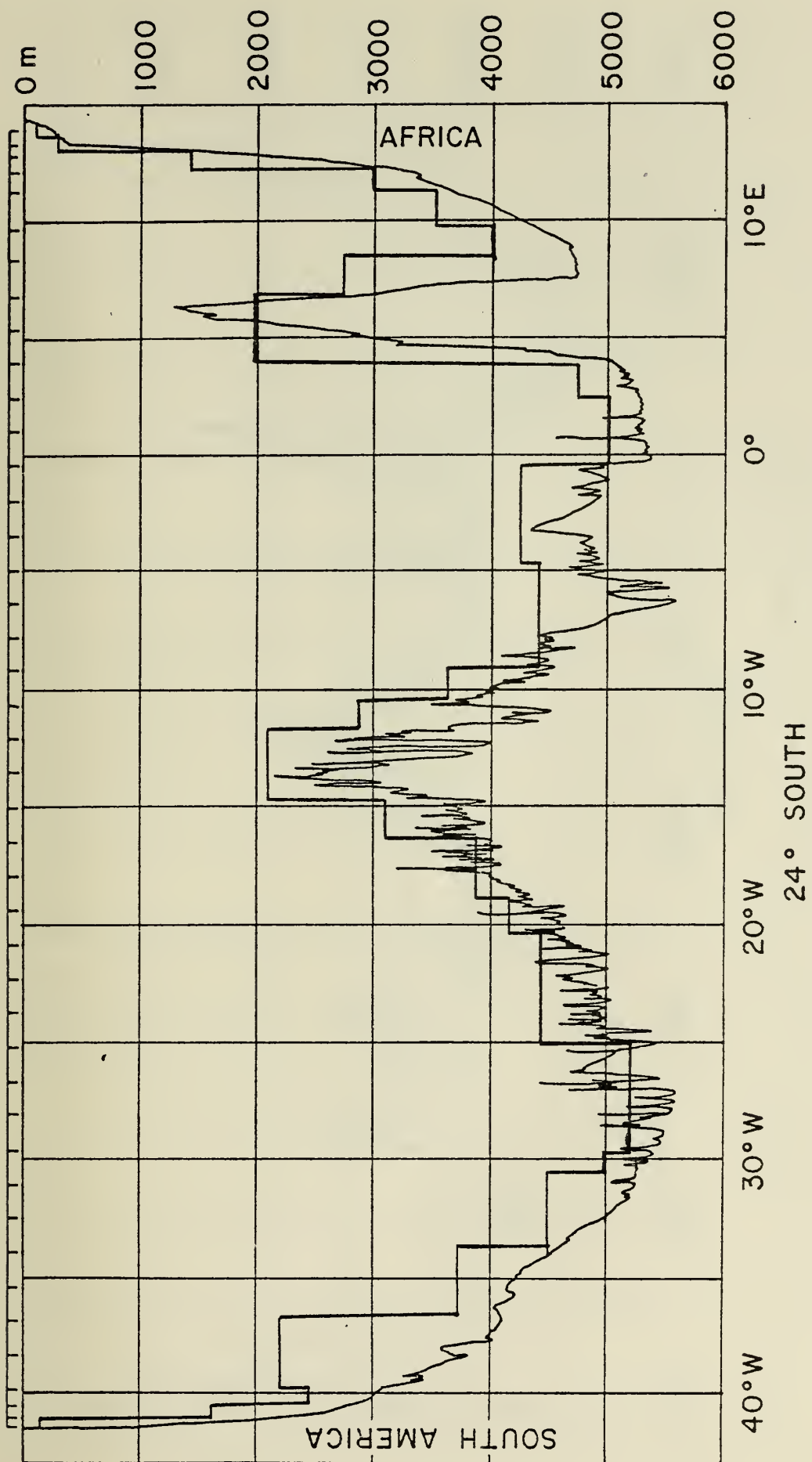


Figure 5. Bottom Peripheral Areas: 24°S Latitude Section.

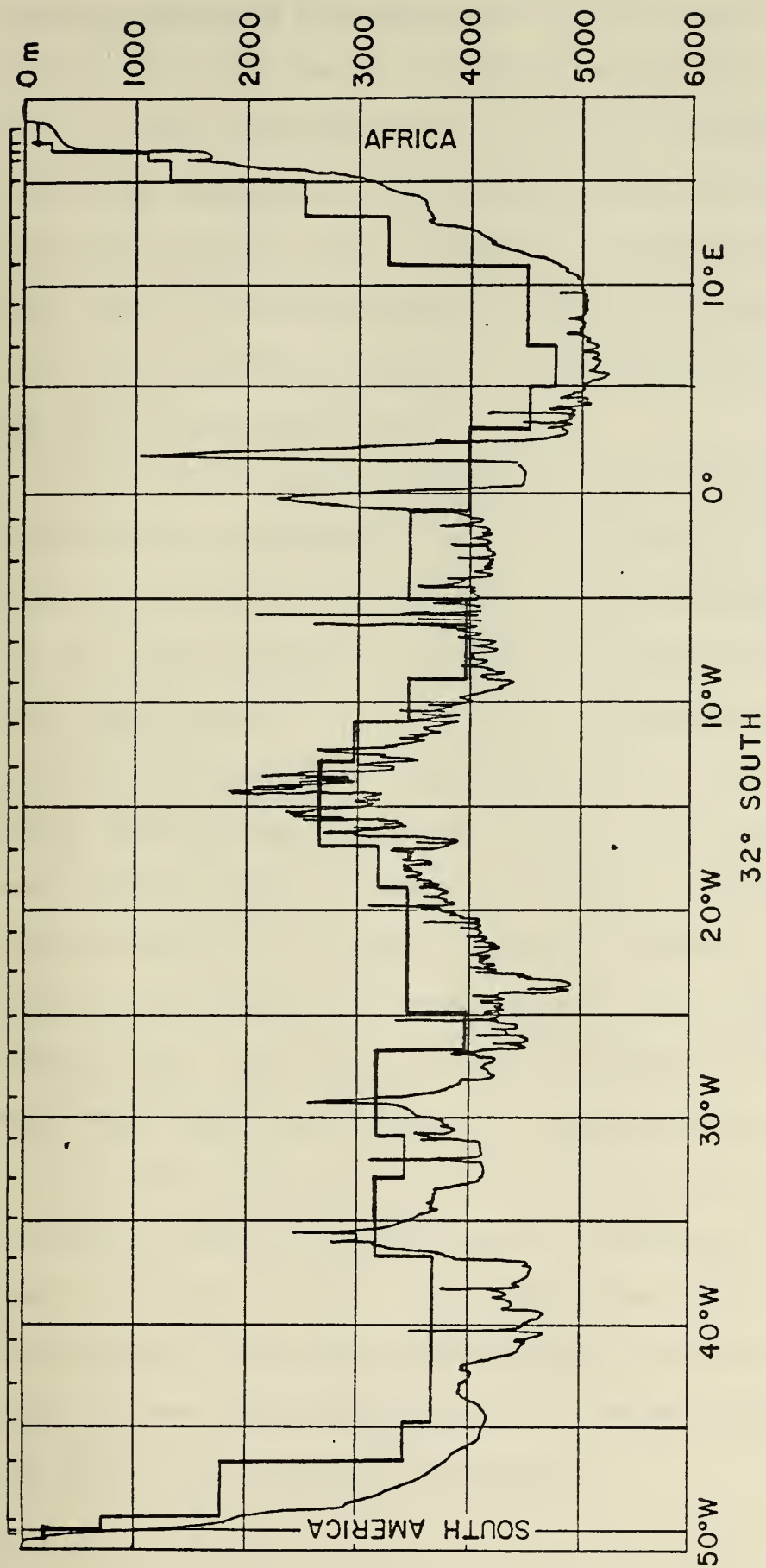


Figure 6. Bottom Peripheral Areas: 32°S Latitude Section.

deepest interpolated mean density and the near-bottom area. The mass transport was multiplied by the deepest average temperature and salinity values to find the corresponding heat and salt transports. The modified program then automatically added these results to the respective transports for the station pair. Consequently, these near-bottom areas are taken into consideration automatically during the search for the level of no motion for which net mass and salt fluxes across the entire latitude section must approach zero.

One potential problem with the method described above is in the accounting for the proper direction of the Antarctic Bottom Water. No Antarctic Bottom Water was identified from the oceanographic data, not because it was not present, but because the Nansen cast did not extend deep enough to sample it. Consequently, the deepest sampled water in the deep ocean stations is always South Atlantic Deep Water, which usually flows southward (poleward). By the method described above, the water below the deepest sounding is assigned a velocity of one half the average velocity at the deepest sounding. Therefore, the direction assigned to the water in the area adjacent to the bottom is usually southward also. The usually northward transports of the Antarctic Bottom Water may be missed entirely by this technique.

The cross-sectional area through which Antarctic Bottom Water flows is small by comparison to the remaining cross section, but not insignificant. A study by Greeson (1974) showed that the bottom peripheral area amounted to approximately ten percent of the total cross-sectional area, with some unknown portion of this area being attributed to the flow region of the Antarctic Bottom Water.

A volume transport of three million m^3/sec is estimated for Antarctic Bottom Water flowing northward across 30°S by Sverdrup et al. (1942). Even smaller values would be expected for Antarctic Bottom Water at lower latitudes. These values are considered negligible when compared with typical transports for even a single station pair in the cross section. Consequently, any bias in transports caused by not detecting the Antarctic Bottom Water in the Nansen casts was considered negligible.

D. ESTIMATING TRANSPORTS FOR THE PERIPHERAL AREAS ADJACENT TO LAND

The portion of the cross-sectional area as yet not accounted for was that of the peripheral areas between the last station on either end of the section and land. Values of mass, salt, and heat transport for these peripheral zones were calculated as follows.

The transport (volume, mass, salt, and heat) within each standard layer in the peripheral zone was considered to be a fraction of the transport for the same layer in the first station pair nearest the end. The fraction was determined by assuming a linear decrease in current velocities toward shore for each horizontal layer, with zero velocity at the beach. Therefore, a value of one-half the layer volume transport for the first station pair was considered representative for the peripheral zone. Next, this estimate was corrected for the difference in cross-sectional area between the first station pair and the periphery by multiplying by the ratio of areas, layer by layer. Finally, the layers were summed to obtain total transports for the peripheral zone.

This method was devised to take advantage of the observed salinity and temperature data for each layer. For purposes of comparison the results were qualitatively evaluated against climatological temperature and salinity data obtained from Fleet Numerical Weather Central's

"Hydroclimatological Data Retrieval Program" (HYDAT) and current velocities from pilot charts. The statistics from HYDAT were consistent with the data of this study. but were not detailed enough for the layer-by-layer estimates obtained by the ratio method. Several of the peripheral areas had negligible cross-sectional areas and their contribution to transport was discarded.

To demonstrate the procedure described above, transports were calculated for a single end zone. Figure 7 illustrates the geometry of the problem and Table II lists the results. As can be seen from Table II, the mass, salt, and heat transports for each 50-meter layer of the adjacent station pairs were multiplied by the ratio of lengths and then by one-half to account for the assumed linear decrease in velocity toward shore.

Table III shows the results for each end zone, the cumulative contribution of the two end zones for each latitude, and a grand total net result for all eight peripheral areas. For the purpose of evaluating total net transports the results were considered negligible since compensating for even the largest value obtained changed the level of no motion across the latitude section by less than one meter.

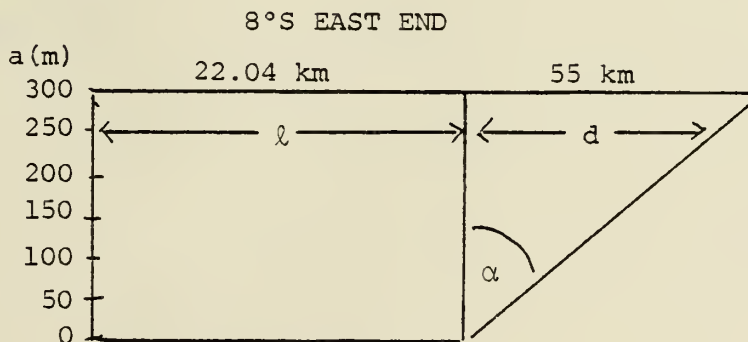


Figure 7. Illustration of the technique for estimating the transports of mass, salt, and heat in the peripheral zones; $d = a \tan \alpha$.

TABLE II

ESTIMATED TRANSPORTS OF MASS, SALT, AND HEAT
IN THE PERIPHERAL ZONES AT 8°S, EAST END

<u>a (km)</u>	<u>R¹</u>	<u>(.5R) x Mass (g/sec)</u>	<u>(.5R) x Salt (g/sec)</u>	<u>(.5R) x Heat (cal/sec)</u>
.300	2.4955	-.22435 ²	-7.64393 ³	-66.92056 ²
.250	2.0796	.02946	1.04579	8.61866
.200	1.6636	.08013	2.85529	23.18796
.150	1.2477	.02327	0.81847	1.57821
.100	0.8318	.00368	0.12073	1.05214
.050	0.4159	.00099	-.03458	-.28034
.000	0.0	<u>0.0</u>	<u>0.0</u>	<u>0.0</u>
Total		-.08880	-2.82923	-32.76393

¹R is the ratio of lengths for each 50 meter layer;

$d = a \tan \alpha$;

$R = d/l = a \tan \alpha / l$.

²(all values times 10^{12})

³(all values times 10^9)

TABLE III

ESTIMATES OF MASS, SALT, AND HEAT TRANSPORTS
FOR PERIPHERAL AREAS AT EACH LATITUDE

<u>Latitude</u>		<u>West End</u>	<u>East End</u>	<u>Total</u>
8°S	Mass ¹	- .06432	- .08880	- .15312
	Salt ²	- 3.41850	- 2.82923	- 6.24773
	Heat ³	-27.66394	-32.76393	-60.42787
16°S	Mass	- .09711	.23887	.14176
	Salt	- 3.53711	8.49962	4.96251
	Heat	-29.37412	69.57869	40.20457
24°S	Mass			
	Salt	Negligible	Negligible	Negligible
	Heat			
32°S	Mass		- .16417	- .16417
	Salt	Negligible	- 5.76357	- 5.76357
	Heat		-47.13947	-47.13947
Grand Total	Mass	- .17553		
	Salt	- 7.04879		
	Heat	-67.36277		

¹ g/sec x 10¹²

² g/sec x 10⁹

³ cal/sec x 10¹²

E. IDENTIFICATION OF WATER MASSES

An additional modification of the existing computer program was effected in order to provide automatic identification of water masses in the South Atlantic Ocean based on salinity, temperature, and depth criteria and additionally to identify and sum mass, salt, and heat transports according to water mass type.

The criteria used to identify the various water masses in the South Atlantic Ocean were found in Defant (1961), Sverdrup et al. (1942), Williams et al. (1973), and Bialek (1967). The specific temperature and salinity for each water mass used in this study were extracted from these works and expanded somewhat to include the transition waters between each water mass type. Table IV lists the temperature and salinity values used in this study to identify the water masses in the South Atlantic Ocean.

No specifications for surface water were listed in the literature; thus, a temperature criterion was established to delineate the mixed layer adjacent to the sea surface.

Figures 8 through 11 depict the various water masses found in the South Atlantic and the level of no motion through the cross section. No Sub-Antarctic Water, Antarctic Circumpolar Water or Antarctic Bottom Water was found. It is reasonable to assume that Sub-Antarctic Water and Antarctic Circumpolar Water were not identified due to the low latitude of the sections. Antarctic Bottom Water, however, was undoubtedly present but went undetected because the data available did not extend deep enough to sample it. Rather than arbitrarily specifying that any water below the last sounding was Antarctic Bottom Water, this water was instead assigned to a Deep and Bottom Water category collectively.

TABLE IV

TEMPERATURE AND SALINITY CRITERIA FOR WATER MASS
IDENTIFICATION IN THE SOUTH ATLANTIC OCEAN

<u>Watermass</u>	<u>Temperature (°C)</u>	<u>Salinity (o/oo)</u>	<u>Reference</u>
Antarctic Bottom Water	< 0	34.65 to 34.67	Defant
Antarctic Circumpolar Water	0-2.5	34.68 to 34.80	All
Sub-Antarctic Water	7.0-9.0	34.10 to 34.68	Defant
South Atlantic Deep Water	7.0-9.0	34.70 to 34.97	Defant
Antarctic Intermediate	2.8-7.0	33.80 to 34.71	Sverdrup and Defant
South Atlantic Central	5.0-18.0	34.45 to 36.10	Williams
Surface	> 18.0		

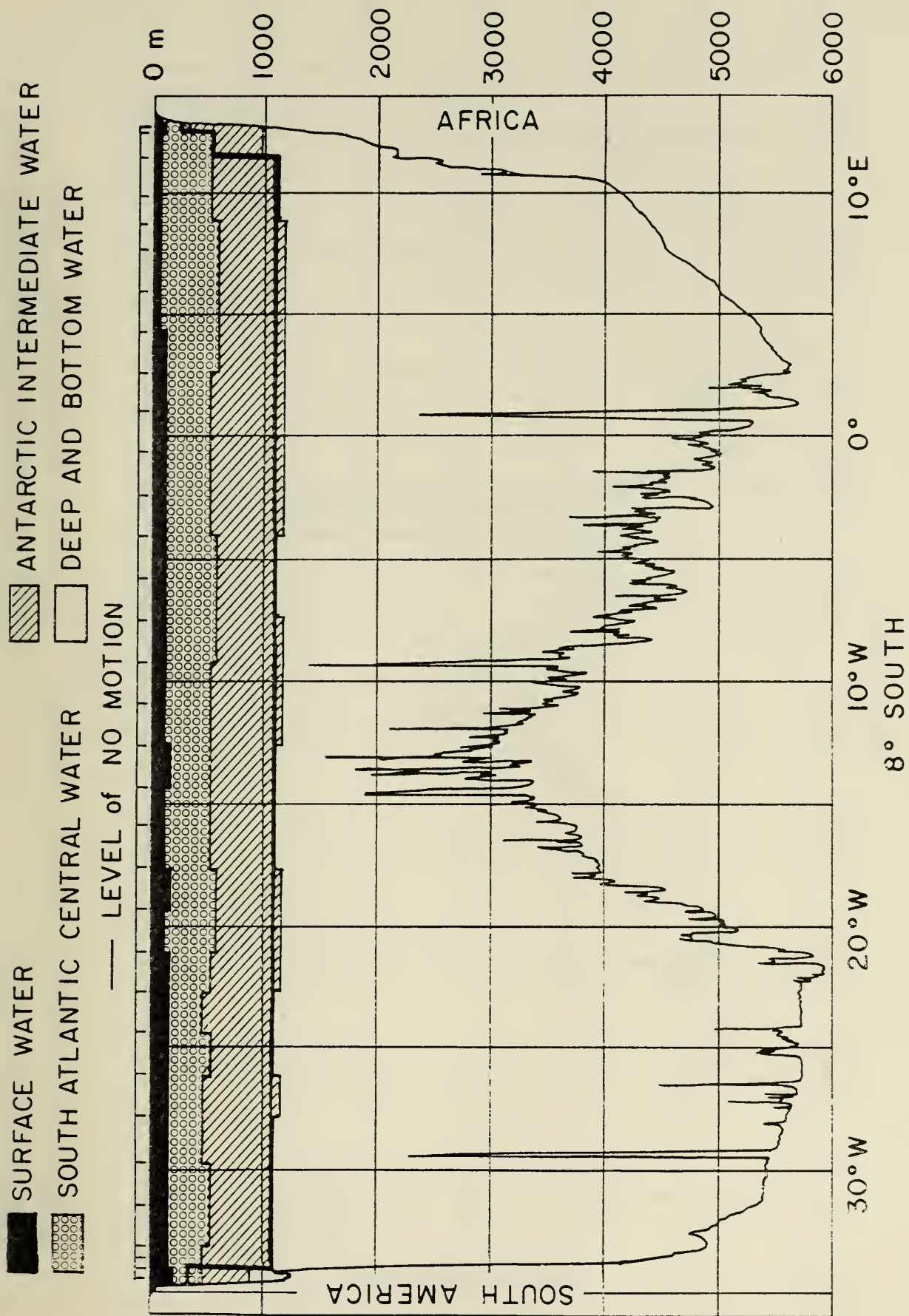


Figure 8. Water Masses and Level of no Motion: 8°S.

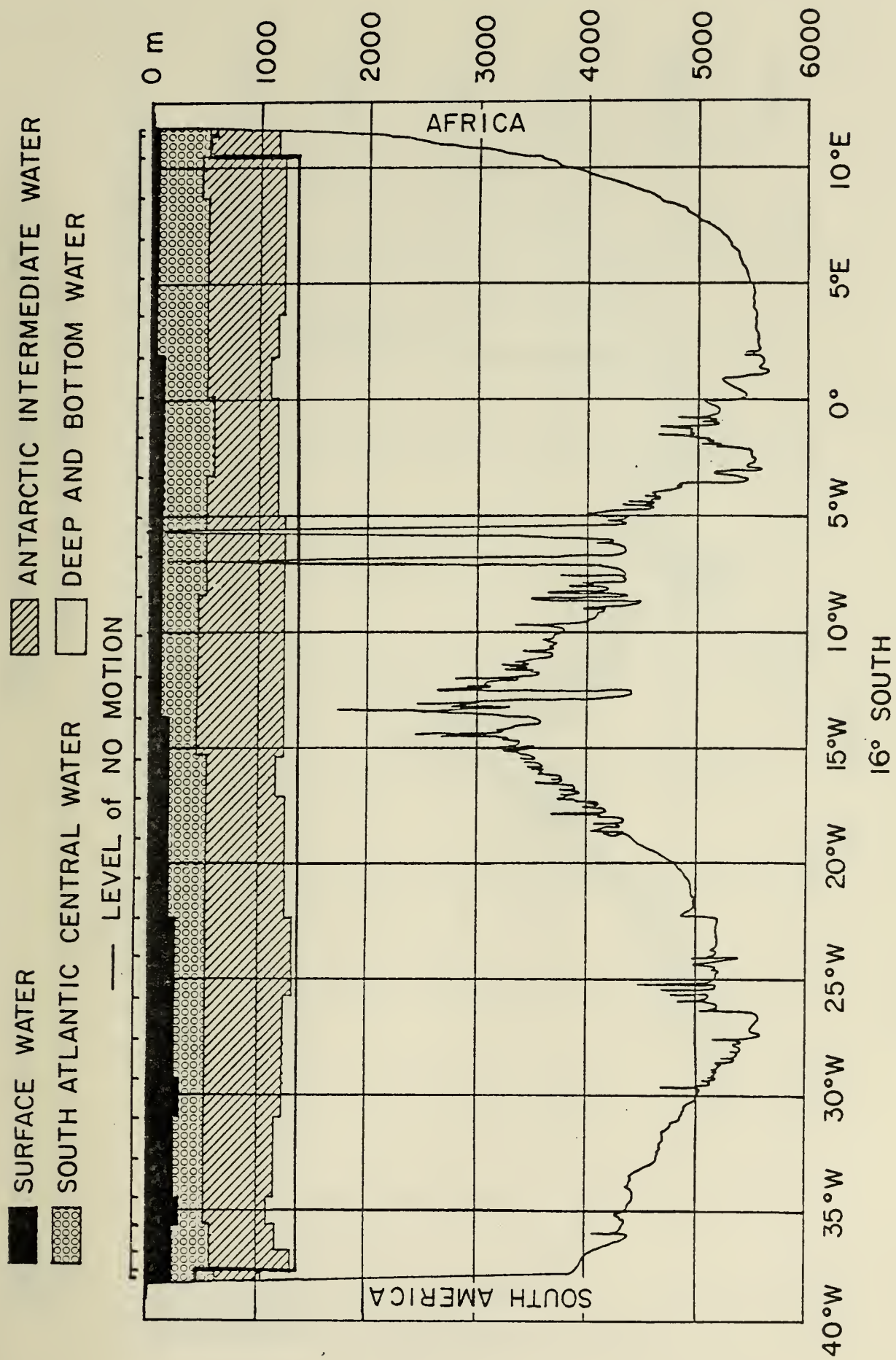


Figure 9. Water Masses and Level of no Motion: 16°S.

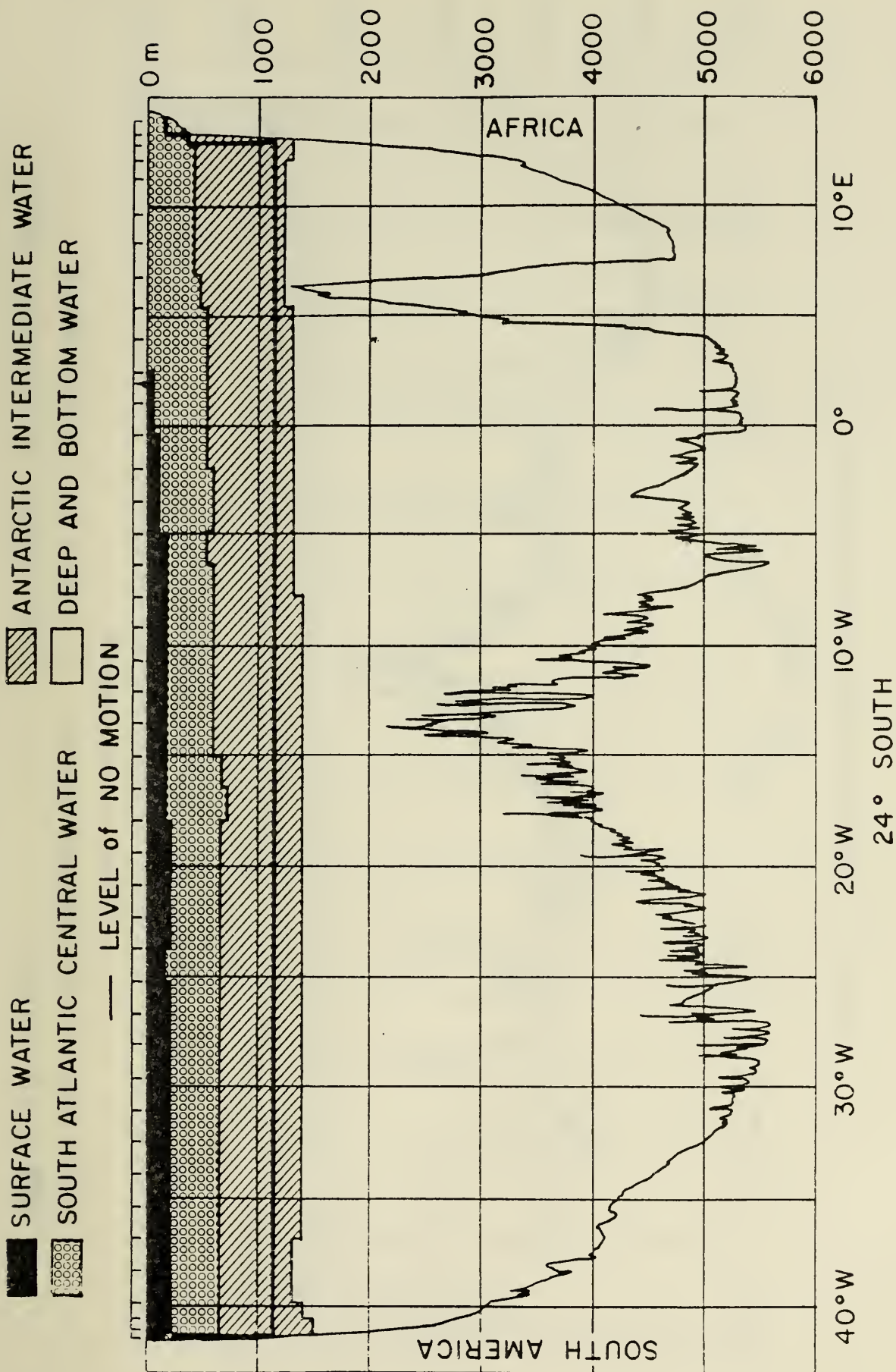


Figure 10. Water Masses and Level of no Motion: 24°S.

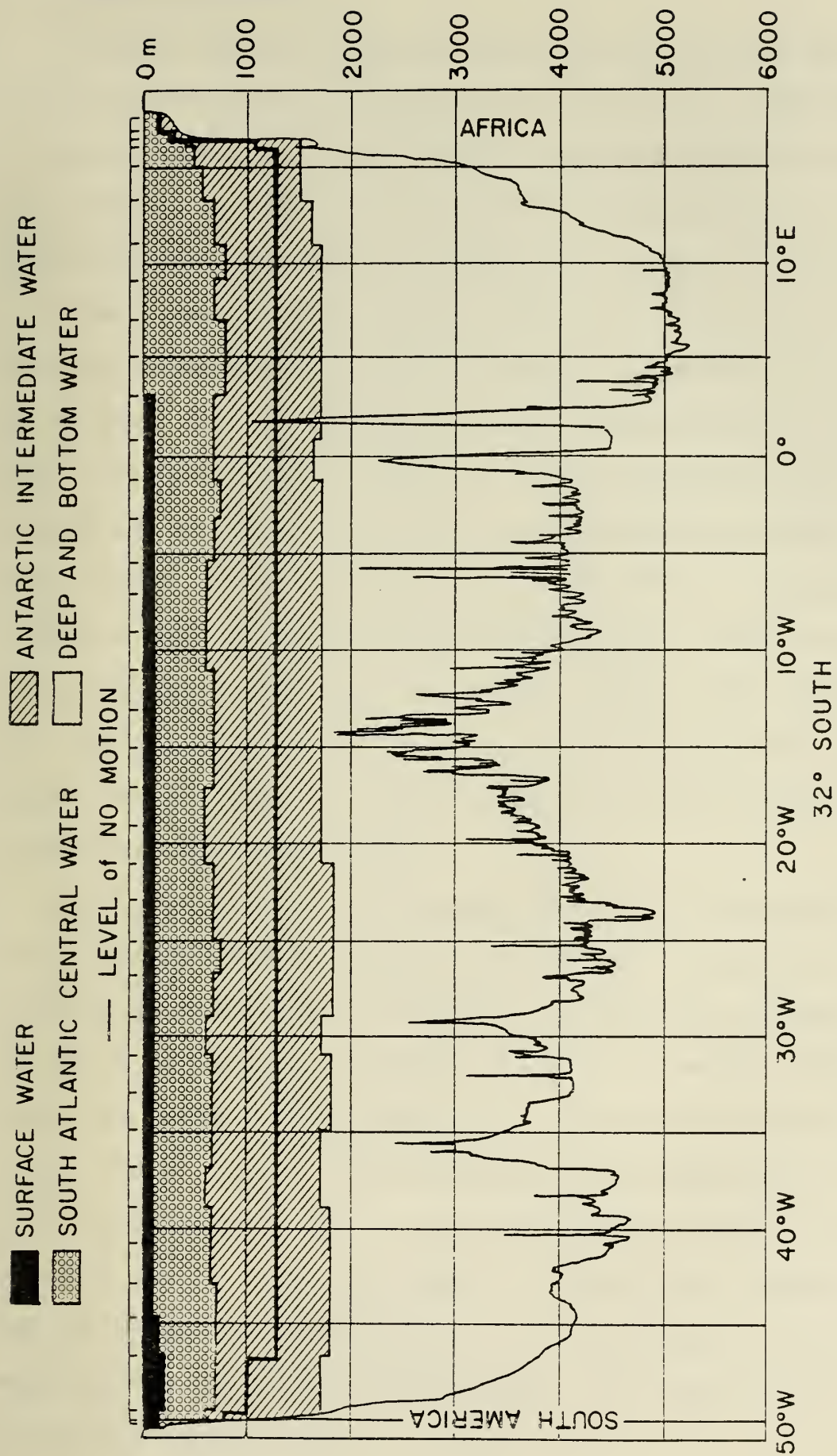


Figure 11. Water Masses and Level of no Motion: 32°S.

F. GENERAL CIRCULATION

In order to study the general circulation of the South Atlantic Ocean the mass transports were separated into three layers: Upper Water (consisting of Surface and Central Waters), Intermediate Water and Deep and Bottom Water. The absolute mass transport for each layer and for each station pair was computed and recorded on the chart at the proper location.

These integrated mass transport figures for each layer at each station pair were combined into a composite value for increments of five degrees of latitude. Figures 12 through 14 give a graphical idea of the net transports involved for each increment. A general circulation pattern was then devised for the Upper, Intermediate, and Deep and Bottom Waters consistent with net mass transports across each latitude circle. To provide continuity of mass and to match observed circulations, series of cyclonic and anticyclonic eddies were constructed. Robinson (1976) reports extensive mid-ocean eddy activity at all scales in the ocean from the sea surface to the bottom thus lending credence to the eddy concept used here in approximating the circulation.

Areas of convergence and divergence are shown as symbols for gain and loss to the layers of water depicted in Figures 17 through 19. These indicate the general areas of upwelling and downwelling required for continuity in the vertical. To further identify the general circulation and examine it in the vertical, geostrophic current velocities and transports of mass, salt, and heat were interpolated in the computer to a rectangular matrix representing a vertical cross section of the ocean and then contoured at various levels by a computer subroutine named CONTUR. An attempt was made to describe quantitatively by size and frequency distribution any eddy features identified by this procedure. The results of this effort are found in Appendix III.

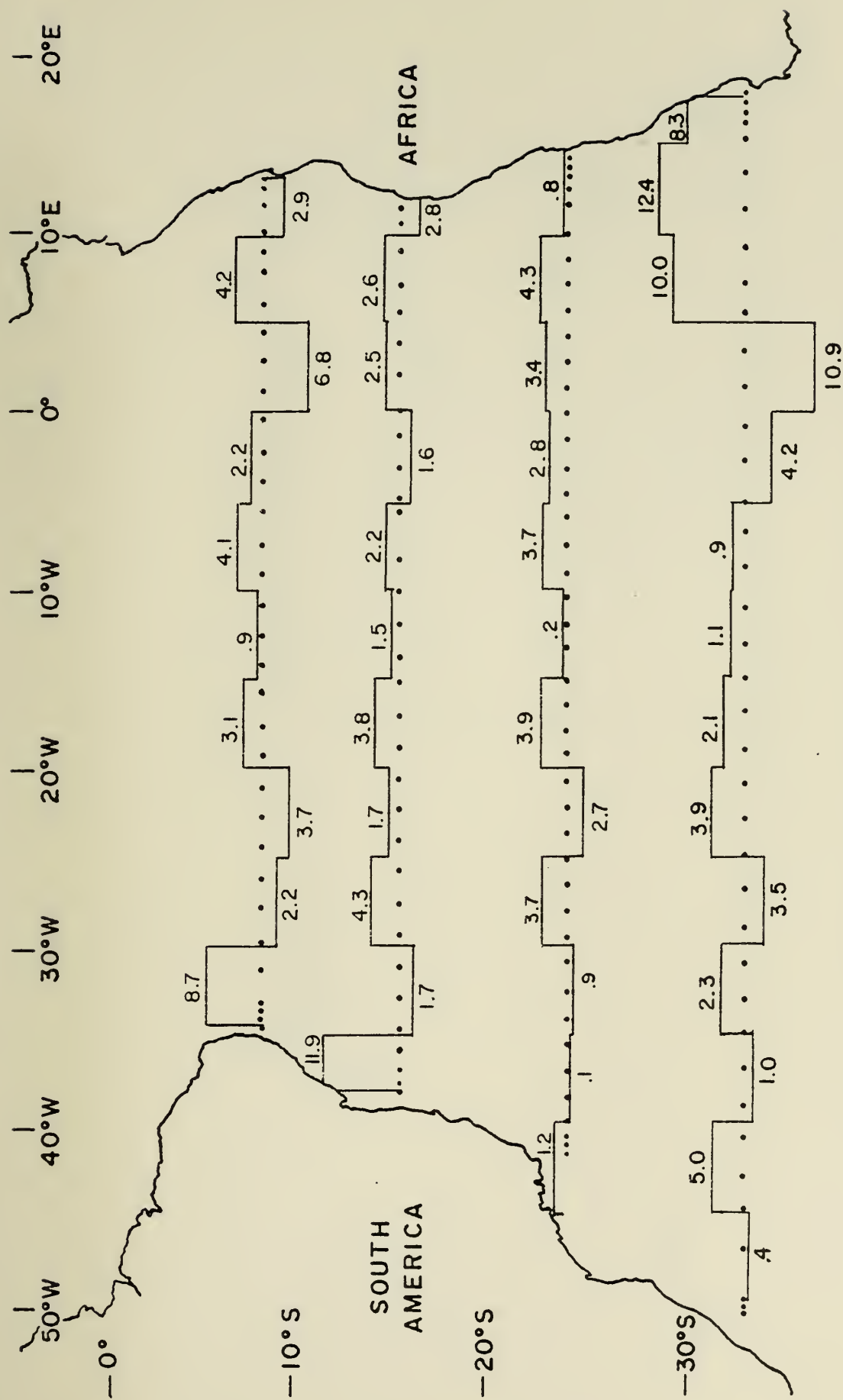


Figure 12. Integrated Mass Transports for Five Degree Increments: Upper Water; (Fig. 17 shows circulation pattern).

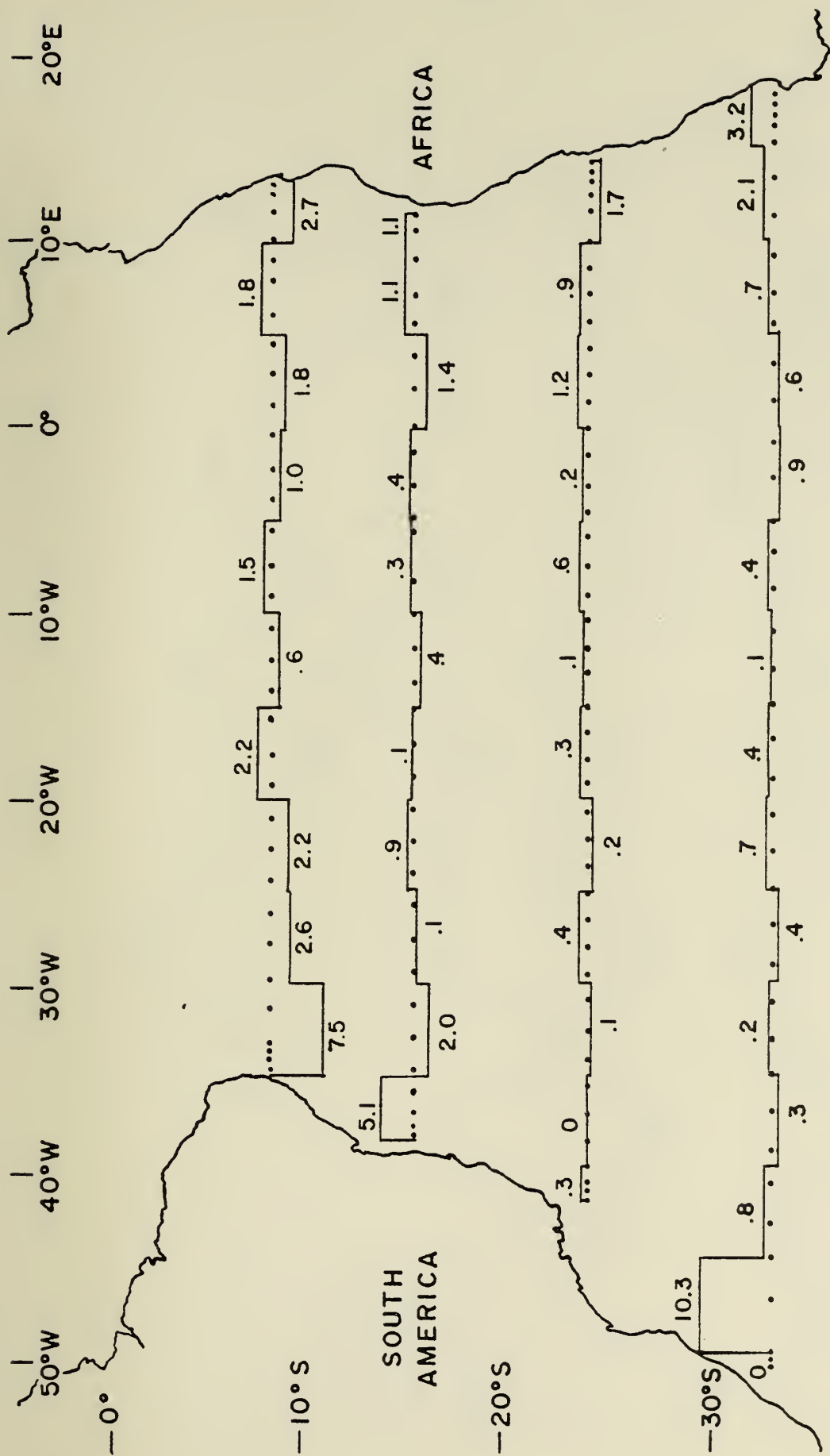


Figure 13. Integrated Mass Transports for Five Degree Increments: Intermediate Water (Fig. 18 shows circulation pattern).

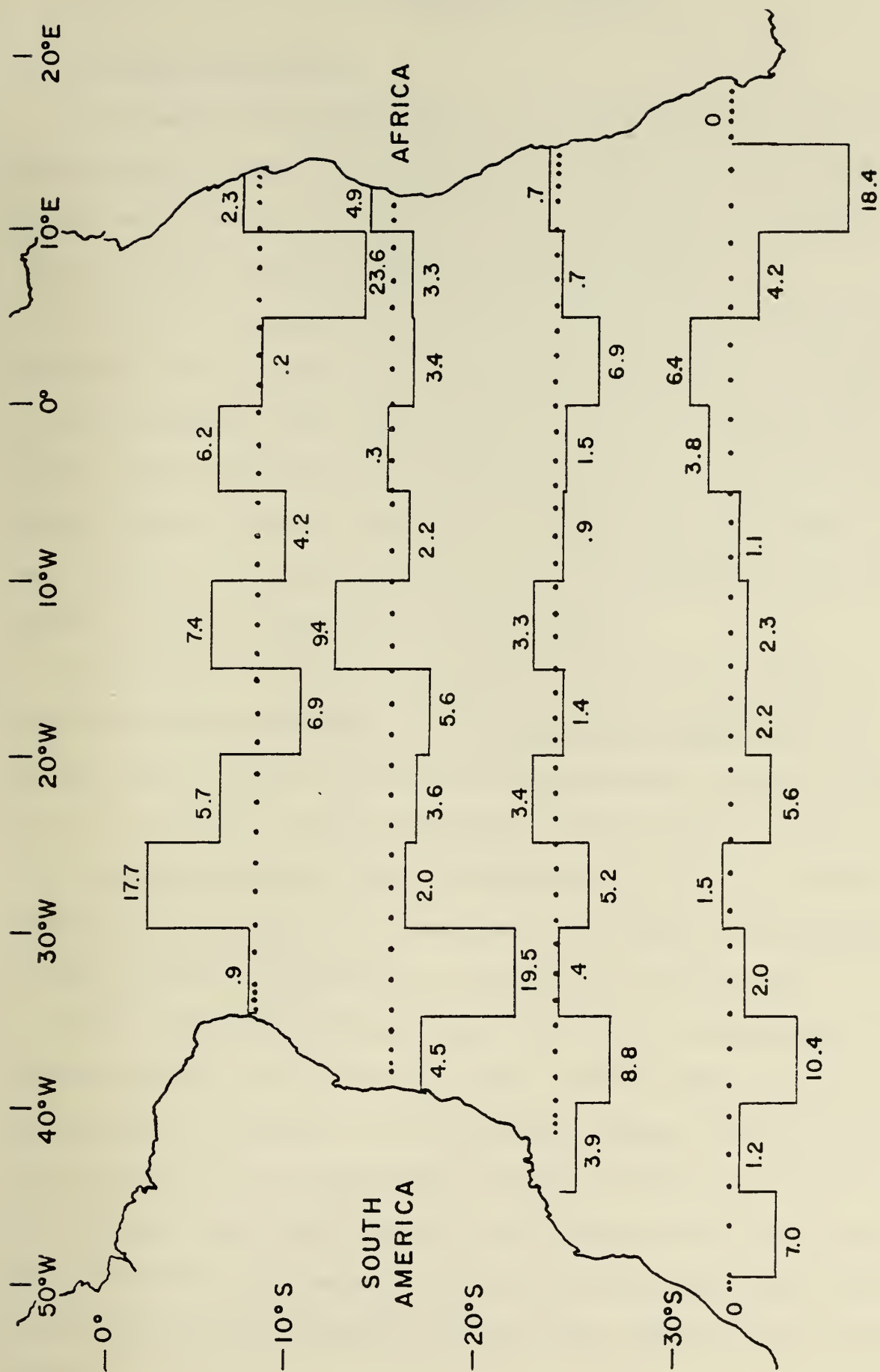


Figure 14. Integrated Mass Transports for Five Degree Increments:
Deep and Bottom Water (Fig. 19 shows circulation pattern).

V. DISCUSSION OF RESULTS

A. THE LEVEL OF NO MOTION

The procedure for determining the level of no motion was taken from Sverdrup et al. (1942) as described in Section II. The resulting depths of the level of no motion obtained in this study for each section are listed in Table V and illustrated in Figures 8 through 11.

Previous evaluations of the level of no motion for the Southern Hemisphere are found in Defant (1961) and Neumann (1954, 1955). A comparison of those obtained in this study with those of Neumann shows the same general trend of deepening with increasing latitude. However, this study showed a deeper level of no motion for the region from the equator to 20°S and a shallower level of no motion for the region between 20°S and 40°S. Figure 15 illustrates the results of each study.

A comparison of the level of no motion surface with isothermal and isohaline surfaces diagrammed in the Atlantic Ocean Atlas (Fuglister, 1960) revealed that the level of no motion followed salinity surfaces between 34.55 ‰ and 34.70 ‰ and temperature surfaces between 3° and 4.1°C. The corresponding sigma-t surface averaged about 27.57 for all of the latitudes in this study. This isopycnal surface might prove useful as a first estimate for the level of no motion at other latitudes.

Defant (1941) and Sverdrup et al. (1942) after an examination of the METEOR profiles to the south of 20°S state that the level of no motion is approximately 1100 meters at 20°S and deepens somewhat toward the south, coinciding with the boundary between Antarctic Intermediate Water and South Atlantic Deep Water. The level of no motion found in this study is also approximately 1100 meters at 20°S and coincides very closely with the boundary between the Intermediate and Deep Water masses for all latitudes studied.

TABLE V

LEVEL OF NO MOTION OBTAINED FOR
EACH LATITUDINAL CROSS SECTION

<u>Latitude</u>	<u>Level of No Motion</u>
8°S	1100 m
16°S	1300 m
24°S	1145 m
32°S	1270 m

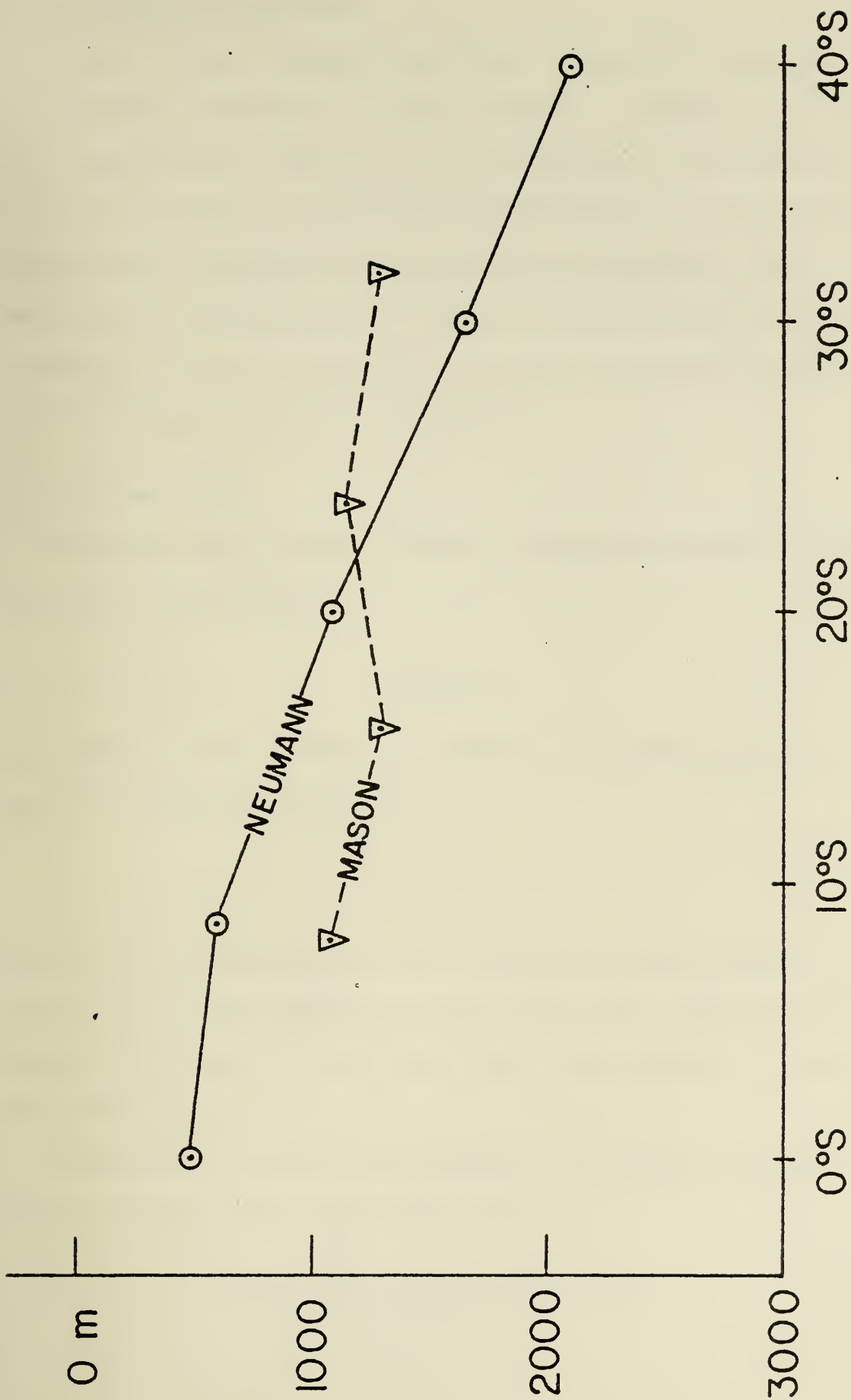


Figure 15. Comparison of Derived Level of no Motion with Previous Estimate by Neumann.

B. MASS AND SALT TRANSPORT

A mass and salt transport balance was attempted at each section as a prerequisite to estimating the heat transport. Attaining a zero net transport value for both mass and salt proved impossible; consequently, zero mass flux was chosen as the primary consideration, with zero salt flux as secondary. Excellent mass continuity and satisfactory salt continuity was attained for each section. Tables VI through IX lists the resulting transports of mass and salt for each latitude section by water mass type and the cumulative total net transport.

C. HEAT TRANSPORT

Meridional heat transport across a latitude section may be represented by the following equation:

$$\sum C_p \bar{T} \rho V_1 A . \quad (6)$$

By assuming the specific heat of seawater at constant pressure, C_p , to be unity, the expression reduced to

$$\sum \bar{T} \rho V_1 A , \quad (7)$$

where A is the cross-sectional area between the station pairs, ρV_1 is the north or south mass transport at each station pair, and \bar{T} is the average absolute temperature for the station pair. The summation is across all the station pairs.

Because mass continuity was required, the net mass transports ρV_1 (north) and ρV_1 (south) must cancel, that is,

$$\sum \rho V_1 \text{ (north)} + \sum \rho V_1 \text{ (south)} = 0 . \quad (8)$$

TABLE VI

TRANSPORTS OF MASS AND SALT
BY WATER MASS TYPE AT 8°S

(Negative values indicate northward transport;
positive values indicate southward transport)

(all values times 10^{12})

<u>Water Mass</u>	Transports	
	<u>Mass</u> (gm/sec)	<u>Salt</u> (gm/sec)
Surface	- 6.21528	-232.87947
Central	- 1.32696	- 47.18784
Intermediate	12.78718	440.85053
Deep and Bottom	<u>- 5.22625</u>	<u>-178.54060</u>
Total for 8°S	.01869	- 17.75700

TABLE VII

TRANSPORTS OF MASS AND SALT
BY WATER MASS TYPE AT 16°S

(Negative values indicate northward transport;
positive values indicate southward transport)

(all values times 10^{12})

<u>Water Mass</u>	Transports	
	<u>Mass</u> (gm/sec)	<u>Salt</u> (gm/sec)
Surface	-11.24442	-413.63354
Central	-13.13231	-461.25879
Intermediate	- 5.12388	-176.45419
Deep and Bottom	<u>29.49049</u>	<u>1029.91431</u>
Total for 16°S	- .01012	- 21.43221

TABLE VIII

TRANSPORTS OF MASS AND SALT
BY WATER MASS TYPE AT 24°S

(Negative values indicate northward transport;
positive values indicate southward transport)

(all values times 10^{12})

<u>Water Mass</u>	Transports	
	Mass (gm/sec)	Salt (gm/sec)
Surface	- 3.40335	-122.69826
Central	-16.98189	-597.16504
Intermediate	- 1.99157	- 68.17680
Deep and Bottom	<u>22.35007</u>	<u>779.98511</u>
Total for 24°S	- .02674	- 8.05499

TABLE IX

TRANSPORTS OF MASS AND SALT
BY WATER MASS TYPE AT 32°S

(Negative values indicate northward transport;
positive values indicate southward transport)

(all values times 10^{12})

<u>Water Mass</u>	Transports	
	<u>Mass</u> <u>(gm/sec)</u>	<u>Salt</u> <u>(gm/sec)</u>
Surface	- .85776	- 29.92361
Central	-25.17276	-881.97144
Intermediate	-16.78152	-576.14258
Deep and Bottom	<u>42.82959</u>	<u>1494.25366</u>
Total for 32°S	.01755	6.21603

However, a balance of the heat transport was not anticipated as a by-product of mass continuity due to the varying temperature properties of the water masses involved. The heat transports calculated by this method were taken as representative of the direction and magnitude of the actual oceanic heat transports across these latitude sections. The resulting heat transports by the various water mass types and the total heat transports across each section are listed in Table X.

Methods of computing heat transports have been proposed by Model (1950), Jung (1955), Sverdrup (1957), Bryan (1962), Sellers (1965), Emig (1967), Vander Haar and Oort (1973), and Bennett (1978). Of these, Model, Sverdrup, Emig, Bryan, and Bennett report estimates for at least one latitude in the Southern Hemisphere (see Figure 16).

Model (1950) uses an empirical and dynamical approach to estimate transports of absolute heat through a latitude section. He estimates the heat transported by main ocean currents using volume transport and temperature information from Sverdrup et al. (1942). By determining the effects of slope currents using oceanographic station data and wind drift currents using monthly wind charts of the South Atlantic an average transport was estimated. Model obtained a figure of 150×10^{12} calories per second towards the north across 30°S in the South Atlantic Ocean.

Sverdrup (1957) used the heat budget equation to obtain heat transport results. He took into account heat exchange by currents, evaporation, condensation, sensible heat, and radiation excess at a given latitude through use of radiation data from Kimball (1928) and evaporation and turbulent heat flux from charts by Jacob (1957). Meridional heat transport for an ocean basin was then calculated by integrating the field of net heating with respect to latitude. A constant of integration was selected to give

TABLE X

TRANSPORTS OF HEAT BY WATER MASS
TYPE AT 8°S, 16°S, 24°S AND 32°S

Heat Transports (cal/sec) across
four latitude cross sections

(all values times 10^{12})

(Negative values indicate northward transport;
positive values indicate southward transport)

<u>Watermass</u>	<u>8°S</u>	<u>16°S</u>	<u>24°S</u>	<u>32°S</u>
Surface	-1853.79395	-3328.71582	- 993.78101	- 250.10114
Central	- 382.53979	-3745.13647	-4861.37500	-7184.11328
Intermediate	3553.36621	-1424.19434	- 554.42651	-4663.28906
Deep and Bottom	<u>-1380.01392</u>	<u>8131.60547</u>	<u>6170.85547</u>	<u>11799.19141</u>
Total	- 62.98145	- 366.44116	- 238.72705	- 298.31207

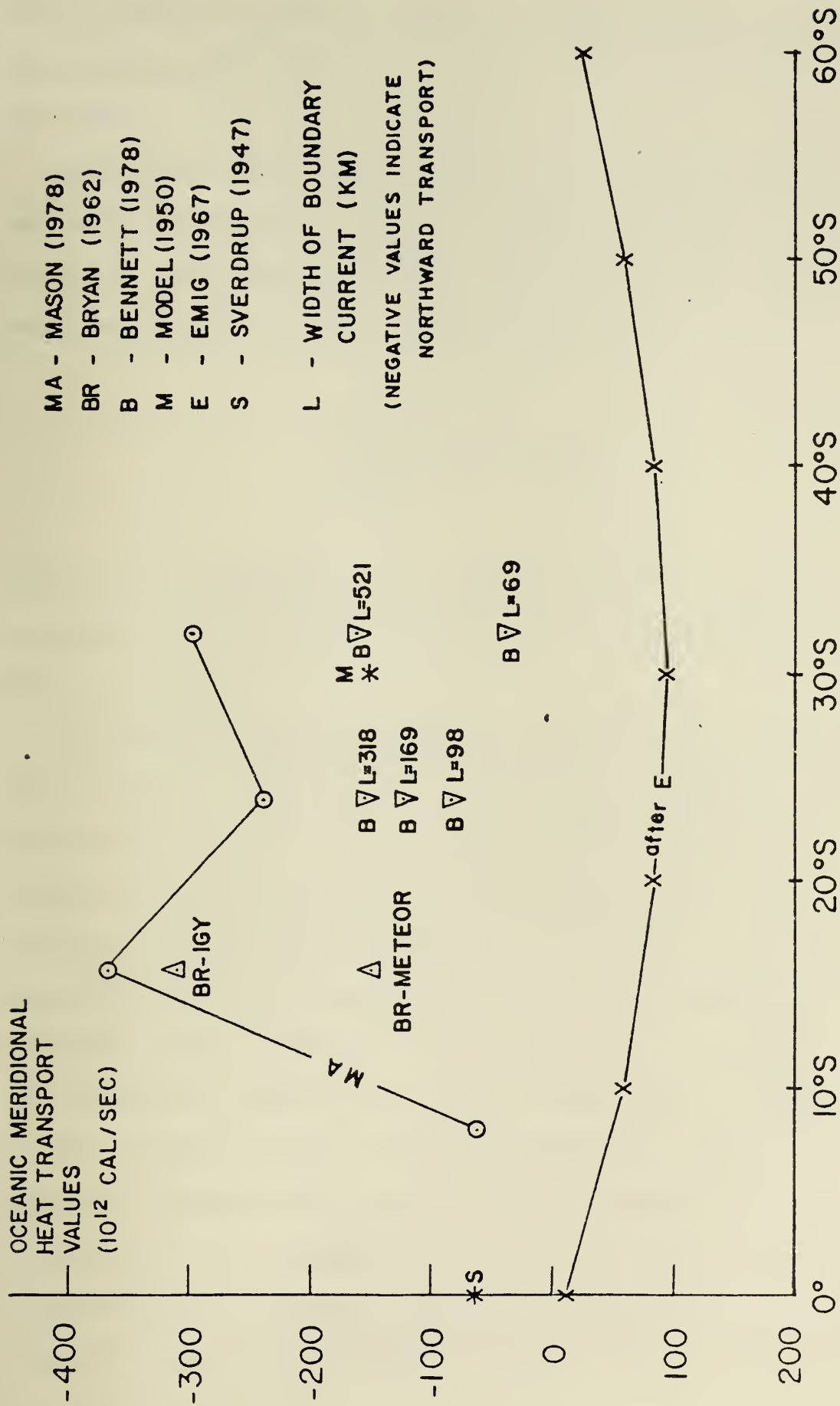


Figure 16. Comparison of Heat Transports Across Various Latitudes with Previous Works.

what he deemed as reasonable results. Sverdrup obtained an estimate of net heat transport across the equator of 67×10^{12} calories per second toward the north.

Bryan (1962) uses a dynamic method for combining hydrographic station data and climatological estimates of surface wind stress to calculate meridional heat transport directly. Basically the method provides an estimated value for the transport integral as given by

$$\int_0^1 \int_{-H}^0 C_p \theta \rho v dz dx , \quad (9)$$

where x is the coordinate in the east-west direction, z is the vertical coordinate, v is the meridional velocity, θ is the potential temperature, and ρ is the density.

The method requires hydrographic data from which the derivative of the geostrophic volume transport is calculated. The method involves measuring the integral of the covariance of the meridional velocity and temperature over an entire vertical cross section of the ocean. Bryan divided this heat transport integral into two parts. One part can be calculated from the hydrographic data alone and is independent of any reference level of no motion. The other part of the integral is calculated from the field of surface wind stress and does require a fixed reference level. According to Bryan, Sverdrup's formula for computing the total integrated transport from the curl of the wind stress vector as used in this portion of the integral provides the most objective way to fix the reference level of no motion. This part of the integral is most important when the transport is influenced by a strong western boundary current

flowing over a shallow shelf which is compensated for by a return flow in deeper water. Bryan attempted to minimize this portion of the integral by choosing cross sections which avoided this effect.

Bryan (1962) calculated heat transports for three South Atlantic sections, all of which indicated a strong northward transfer of heat toward the equator for two 16°S and one 24°S sections. The IGY section at 16°S has a heat transfer twice that of the METEOR section at 16°S taken many years earlier. Bryan noted that circulations in the vertical meridional plane played the most important role in transports, thus confirming Jung's (1952) proposal that heat transports by such circulations in the ocean could be significantly different from those by similar atmospheric circulations at mid-latitudes.

Bennett (1978) employed Bryan's (1962) method using IGY data in the South Atlantic with differing results. Bennett begins with the same total energy transport integral as Bryan, but separates the integral into a sum of five integrals for evaluation. Bennett also employs an L parameter characterizing the width of the western boundary current. His different values of heat transport for the same latitude as illustrated in Figure 16 are due to his different guesses for the width of the boundary current. For all values of L chosen, however, Bennett's results showed strong northward (equatorward) heat transports at 24°S and 32°S .

Emig (1967) evaluated heat transports in the Atlantic Ocean by using the heat flux charts of Budyko (1962). The heat flux divergence for a latitude band was calculated as a residual by Sverdrup's heat budget method and then integrated to yield the heat transports. The boundary condition imposed was that all heat transport across 70°S be zero. The results of Emig's study are illustrated in Figure 16 and are the only estimates

which indicate a southward (poleward) heat flux across the latitude circles in the Southern Hemisphere.

The results of the present thesis study show heat transports of the same order of magnitude and same direction (northward) as in the majority of the previous cited works. The results for 16°S agree quite closely with Bryan's results using the same data and a different method. The results for 24°S and 32°S , however, are almost twice as large as those of Bryan. Results from Bryan, Bennett, and Model, however, all agree with the direction of heat transport obtained herein.

It is surprising to note the equatorward flux of heat across these Southern Hemisphere latitude sections as obtained by Model, Sverdrup, Bryan, Bennett, and Mason. The usual concept of the earth's heat budget would seem to suggest just the opposite result. Ordinarily, the heat balance is described as a poleward flux of heat in both atmosphere and ocean to offset the sun's excess radiation in the tropical regions and deficit in the polar regions. Indeed, this must be the case averaged worldwide, since, over time periods of a century or so, the tropics are not getting warmer nor the poles colder. However, the results of this study and the consensus of previous works indicates that for the South Atlantic at least the oceanic heat flux is in a direction opposite to that expected within the entire fluid envelope.

Bryan (1962) and Bennett (1978) examined several reasons for the unexpected results. Bryan (1962) implied that many of the earliest estimates of heat flux concentrated on transports by horizontal currents and ignored circulations in the vertical plane associated with the thermohaline circulations as originally proposed by Jung (1952). Bryan's results show that while vertical circulations are weak in terms of volume transport,

they dominate the heat transport. It is, therefore, the warmer surface currents with a net northward flux which dominate the net southward flux of cooler deeper water in terms of absolute heat content. However, Bryan does state that the spacing of hydrographic stations is not dense enough to define the role of transient meanders which may have a significant effect on heat transport. For example, Newton (1961) reports that a single Gulf Stream meander can lead to a meridional heat transport of 1 to 2×10^{14} calories per second, a value larger than many of the net heat transports for an entire latitude section. Meanders and eddies in the South Atlantic are not defined sufficiently so as to estimate their effect on the METEOR or IGY data.

Bennett (1978), in agreement with Bryan states that conventionally spaced stations do not resolve the mid-ocean eddy field; however, he does attempt some estimate of eddy flux contributions to heat flux. He concludes that even though the eddy contributions are not negligible, they do not account for the unexpected northward heat flow. It is the large scale flow which is responsible for the northward heat flux, and, although eddies introduce variability into the heat flux estimates, they do not dominate the results.

It appears that this northward oceanic heat transport must be compensated by either the atmospheric heat transport of the Southern Hemisphere, or by oceanic transports southward in other Southern Hemispheric oceans.

Another possibility is that the northward oceanic heat transport is a seasonal effect which may be compensated by a reversal in another part of the year. It is to be noted that three of the cross sections were associated with the Southern Hemispheric autumn season and only the 24°S cross section was from the Southern Hemisphere spring season. It is

possible that the oceanic heat transports may be equatorward during these transition seasons and poleward at other times.

D. GENERAL CIRCULATIONS BASED ON MASS TRANSPORT

The general circulation pattern was drawn according to the procedures described in Section IV-F. The resulting eddy circulations are consistent with the pattern of mass transport vectors illustrated in Figures 17 through 19.

Eddy circulations in the North Atlantic have been studied extensively by Iselin (1936, 1940), Fuglister (1947, 1963, 1971), Iselin and Fuglister (1948), Fuglister and Worthington (1951), Barrett (1963), Richardson (1976), and Parker (1971). The eddy fluctuations discussed in the literature are usually associated with the Gulf Stream, but eddies of similar characteristics occur in the other oceans. The typical eddy is a low frequency mesoscale phenomenon with a diameter between 100 and 200 kilometers. Robinson (1976) described the mid-ocean eddy as a feature orders of magnitude more energetic than the main flow. These eddies exist as cyclonic and anti-cyclonic rings extending from the surface to the bottom as measured in the MODE-I experiment.

Only eddies the diameter of one station pair or greater are detectable by the method used in this thesis. Most of the eddies persist with depth through the surface, central and intermediate water, and then reverse their direction of rotation in the deeper regions. This reversal of circulation with depth has been reported in the Northern Hemisphere by McCartney, Worthington, and Schmitz (1978).

Figures 17 through 19 indicate the derived circulation system, depicting a hypothetical gyre pattern for the South Atlantic which best explains some of the observed features. All mass units are in terms of 10^{12} gm/sec.

1. The Circulation in the Upper Water

The Benguela Current, powered mainly by the prevailing southeast trades, is a slow-moving current flowing north along the western coast of Africa. It is most constant in speed and direction between Cape Agulhas and 25°S with well-defined nearly stationary boundaries. North of this region there is a confused coastal part and a steady oceanic part of the current (Boisvert, 1967). Figure 17 shows the narrow flow at 30°S broadening and becoming more zonal as it progresses northward. A net northward flow of 15.6 units is comparable with 16 units derived by Sverdrup et al. (1942) for the same current. Some convergence and sinking, 2.3 units, is seen in the area of the Subtropical Convergence Zone. The Atlantic South Equatorial Current is clearly seen as the more zonal westward flow between 16°S and 24°S. North of 15°S a more confused gyre pattern is pictured with large convergence, 16.8 units, between 15°S and 8°S. The cyclonic gyre centered at 16°S, 17°E matches geostrophic calculations by Moroshkin et al. (1967). The less distinct westward flow of the Atlantic South Equatorial Current between 8°S and 20°S matches the flow described by Mazeika (1968) who detected both surface and subsurface geostrophic currents flowing eastward in this region.

Notably absent in this depiction is the expected strong Brazil Current which flows southwest parallel to the Brazil coast. Sverdrup et al. (1942) estimated 10 units of transport in a southerly direction across 30°S for the Brazil Current as compared to only one unit in Figure 17. Indeed, further north the Brazil Current even appears reversed. In view of the fact that the surface currents for the area compare favorably with Sverdrup's estimates, and yet the volume transports do not, the disagreement may stem from the great variability in the Brazil Current.

The Brazil Current is the southward extension of the Atlantic South Equatorial Current which divides at approximately 10°S . The seasonal boundaries and speeds are more variable than most other major currents and its variation in speed and direction is greater than the Atlantic South Equatorial Current from which it originates. Numerous counter-currents exist from seasonal increases in the river discharge of the Rio de la Plata, a coastal extension of the Falkland Current, and strong tidal rotations. The surface currents particularly exhibit both clockwise and counterclockwise rotations from tidal influences with reversals and diurnal inequalities adding to the confusion (Boisvert, 1967).

The variability of the Brazil Current could affect this study in several ways. If the Brazil Current were exceptionally weak at the time of measurement the lack of influence in the surface and central waters would be explained. This study of circulation patterns by mass transport vectors indicates that the strength of the southward flowing western ocean boundary current is concentrated in the Deep and Bottom Water (Figure 19).

Secondly, if the Brazil Current were very narrow in the upper reaches of the water column, its contribution to the mass transport would be small due to the reduced cross sectional area through which it flows. The depiction of circulation through the vertical cross sections at each latitude are to be found in Appendix III; it is apparent that the southward flowing currents in the region of the Brazil Current are of high velocity but small in areal extent.

Thirdly, a local anomaly in the level of no motion would cause an error in the absolute velocities which would reduce the effect of the Brazil Current. It is doubtful that such an error would extend across the entire cross section since the remainder of the circulation picture closely matches observations and previous estimates of volume transports.

Finally, the more northward extension of the Falkland Current and more southward extension of the Guiana Current during the local autumn (March-May) season, when observations for the 8°S, 16°S, and 32°S cross sections were conducted, may explain the reduced value for southward transport.

Sverdrup's values for transport are in terms of volume transport converted to cm^3/sec , whereas this study used mass transport, with gm/sec units. A comparison by Cummings (1977) showed less than a 2.7% error in equating these two transports.

2. The Circulation in the Intermediate Water

Quantitative volume transport information below the surface of the South Atlantic is scarce. Sverdrup et al. (1942) estimates a net northward transport across 30°S of 9 units for the intermediate level compared with the 16.7 units obtained in this study across 32°S. For the remaining latitudes general trends are apparent. Some deeper elements of the Benguela Current and Atlantic South Equatorial Current systems are evident in the western and middle portion of Figure 18 at these depths. The transports are generally weaker in this layer than for any other and circulation patterns are not well defined.

3. The Circulation in the Deep and Bottom Water

The primarily southward transport of deep water normally observed in current studies is verified in Figure 19. There is a distinct southward mass transport along the westward boundary and a total net southward transport across 16°S, 24°S, and 32°S. Sverdrup's (1942) estimate of a southward transport of 18 units by the deep water is less than one half of the estimate of 42 units obtained here. The northward flowing Antarctic Bottom Water was not detected by the Nansen casts and is not seen in Figure 19. Consequently, the computer attributed its contribution

to the more southerly flow of the Deep Water by default. The northward contribution from Antarctic Bottom Water is only approximately 3 units at 30°S according to Sverdrup et al (1942). Therefore, the abnormally high estimate of mass transport for Deep and Bottom Water combined is not explained by lack of detecting geostrophic currents in the Bottom Water. It does represent an approximation for geostrophic transport based on accurate station data.

VI. CONCLUSIONS

This study used the classical dynamic approach for calculating geostrophic currents to determine mass, salt, and heat transports using oceanographic station data. The results showed an equatorward heat flux in the subtropical South Atlantic at all the latitudes studied. The direction of the flow agreed with the majority of previous estimates by Sverdrup et al. (1942), Bryan (1962), Bennett (1978), and Model (1950). The magnitude, however, was in most cases greater than previous works, with rough agreement with Bryan (1962) at 16°S, and values almost twice as large as the average for Bennett's results for 24°S and 32°S. It is concluded that this unexpected equatorward heat transport is due to warmer surface currents with a net northward flux carrying more energy northward than the deeper cooler waters carry southward.

A level of no motion was experimentally determined in the subtropical South Atlantic which had a trend of deepening with increasing latitude similar to previous results, but did not deepen as sharply with increasing latitude as that of Neumann (1966). The level of no motion was closely related to the sigma-t surface of $\sigma_t = 27.57$ and was most often located near the bottom-most boundary of the Antarctic Intermediate Water mass.

The method employed also provided a useful picture of the absolute geostrophic velocities to be expected in the region. The derived circulation based on mass transport figures corresponds closely with observed circulations, and for the first time demonstrate a quasi-synoptic view of the major transport mechanisms in the South Atlantic.

APPENDIX A: GEOSTROPHIC DATA

MASS TRANSPORT AT 8 DEGREES SOUTH
UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
120/	1.88230	-0.70249	8.15118	0.0	5.56639
119/	1.82971	-4.56023	2.79065	25.19501	36.09235
118/	1.34928	-3.33438	-0.97540	-21.09819	-23.06550
117/	1.1144	-3.06917	-1.06866	-2.48235	-12.27005
116/	1.5903	-4.49622	-1.57132	-2.53545	-12.27095
115/	1.47938	-0.00939	-1.59741	0.53583	-1.03790
114/	1.4400	1.82823	3.91722	-6.38871	-1.53714
113/	1.5928	0.94075	0.17864	-10.34507	-1.53799
112/	1.02896	-1.86410	-0.67738	-17.75407	0.21319
111/	0.81250	1.88095	0.27711	-8.28131	-5.02188
110/	0.49441	1.38104	-0.58703	13.60081	-5.95626
109/	0.26246	-1.89458	-0.73290	-1.07748	-2.54592
108/	0.05246	-0.53805	-0.02422	-17.83577	-5.17469
107/	1.83268	0.82817	0.02422	-6.09077	-1.25109
106/	0.53581	1.50807	2.15284	-5.72872	-1.33335
105/	0.73520	-2.27095	-2.18177	-8.09078	-1.33335
104/	0.64618	-1.00963	-2.08503	-16.22862	-1.25032
103/	0.58449	-1.83036	-0.85035	-11.17195	-1.56042
102/	0.11084	-1.25778	0.37192	-17.07691	-1.56042
101/	0.59020	-2.46881	0.33077	-25.08276	-20.29463
99/	1.42171	1.09381	-1.52495	-17.16035	-2.67879
98/	0.24708	-4.09381	-3.33776	-23.75642	-23.42538
97/	0.84085	1.03261	-0.29237	-16.33533	-16.68773
96/	1.01364	3.53671	1.12494	-6.51923	-2.57013
95/	0.52146	0.09891	0.56948	6.48532	6.24551
94/	0.0791	-6.55735	-2.19844	-27.89127	-14.23144
93/	0.34976	-0.04979	-0.05979	-2.89127	-28.23250
92/	0.24557	-0.23697	0.04855	0.0	-5.69498
91/	2.63234	0.35993	2.70271	0.0	-0.05249
90/	0.15148	0.09899	0.0	0.0	0.0
TOTALS	-6.21528	-1.32696	12.78718	-5.22625	0.01869

SALT TRANSPORT AT 8 DEGREES SOUTH UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
120/	11750	-25.05519	280.78760	0.57593	187.01491
119/	103464	-160.06461	96.26347	905.23242	1265.934848
118/	103283	-116.06352	-33.66789	-733.23242	-822.34082
117/	103237	-124.46971	-36.88582	-108.00774	-2292.915553
116/	103237	-157.30606	-57.69824	-17.20662	-431.98950
115/	104836	0.26382	137.00020	17.98528	-90.79945
114/	104805	63.87830	137.22633	22.2208	33.60054
113/	10482	32.87830	5.95010	413.80762	36.79395
112/	10482	-65.25465	-23.43983	358.62915	195.70760
111/	10482	170.85774	78.48370	-268.24194	10.07813
110/	10482	-100.91823	20.26642	-288.90332	-313.04199
109/	10482	-119.00336	-51.32576	474.77560	-80.98108
108/	10482	29.37032	25.30638	37.61560	92.666
107/	10482	52.42680	0.82919	-274.48291	-177.92606
106/	10482	114.71849	98.28232	-227.10895	3408847
105/	10482	-187.02287	-74.74622	-1304.18584	-466.30884
104/	10482	-35.36215	-67.36122	-566.54224	-131.40698
103/	10482	-39.42845	-29.84060	-477.66523	-531.57275
102/	10482	-86.28253	73.59808	-575.31323	-569.12061
101/	10482	-89.42661	-52.67293	-873.84589	-734.27197
99/	10482	142.59671	114.16592	63.89456	817.87223
98/	10482	38.36366	-140.10126	-229.16578	58.87280
97/	10482	-11.27655	-10.18549	-572.14404	-563.16382
96/	10482	124.09825	38.67529	-227.05609	-94.60527
95/	10482	3.81034	-15.95375	-256.62373	230.34010
94/	10482	-230.71710	-15.67529	-156.03687	-98.65443
93/	10482	-8.38084	-2.07183	-974.08890	-79.57765
92/	10482	13.57398	93.44139	-81.00	195.30275
91/	10482	3.54334	0.0	0.0	-1.57713
TOTALS	-232.87947	-47.18784	440.85083	-178.54060	-17.75691

HEAT TRANSPORT AT 8 DEGREES SOUTH
(CAL/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
120/	554.22046	-203.39177	2265.06470	0.0	1507.45264
119/	844.30664	-1298.46777	777.62256	7179.37109	10099.76563
117/	555.00122	-1949.93408	-2277.17896	-8537.00391	-6504.11328
116/	1018.76831	-198.86005	-2297.42798	-892.90210	-2366.95825
115/	-1063.41577	-1274.24536	-465.62702	-692.19604	-3395.48167
114/	-442.72046	2.16671	-443.27441	1339.36641	-7744.46167
113/	431.33472	517.40601	1106.56812	-1735.79761	-319.51173
112/	-638.79512	2266.57584	-189.11691	-3265.04587	-1504.45897
111/	238.83308	-1380.18774	-633.11108	-22112.49634	1539.63550
110/	148.06967	388.08813	163.62822	-2281.98755	-1582.20166
109/	-177.41840	-387.38036	-403.90845	-22752.44922	-2443.79712
108/	-611.14551	-153.88748	-204.15976	32798.39551	-670.08496
107/	-545.24170	237.91399	6.94573	-21770.18604	-1380.08496
106/	159.65637	424.64038	792.57275	-1757.26978	-3134.13516
105/	-813.94971	-929.42944	-599.55542	-1757.26978	-3750.07275
104/	-194.02765	-705.03784	-505.60620	-1401.14043	-1006.76880
103/	-191.56374	-286.25586	-703.62671	-4480.88965	-3301.19434
102/	-173.22946	-519.70898	-237.15720	-3300.88965	-4227.98438
101/	-132.23147	-699.43799	1593.22036	-4738.82031	-5781.50781
100/	-114.58414	-724.69629	424.56665	-6918.96948	-4781.78906
99/	-114.27710	1155.53955	-424.56665	507.93235	-755.87744
98/	-420.47563	1311.26857	-928.71948	-1976.93235	527.33057
97/	249.09895	-91.26857	381.55988	5520.48438	6461.21094
96/	-300.09424	1006.03516	-381.32264	-4746.83740	-4444.21094
95/	-153.24223	31.07802	158.72154	-1796.69336	-727.57007
94/	-156.14966	-1867.98901	-611.48810	-1796.69336	1822.29199
93/	-102.68407	-67.62256	-158.95752	-7641.33496	-4012.15674
92/	172.18622	107.62256	-13.35122	-641.33496	-7768.41992
91/	780.03223	28.71562	750.07471	0.0	1638.06299
90/	-45.34482	-107.62256	0.0	0.0	-16.56920
TOTALS	-1853.79395	-382.53979	3553.36621	-1380.01392	-62.98145

MASS TRANSPORT AT 16 DEGREES SOUTH UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
121/	-0.44618	-0.16719	3.02564	0.0	2.41227
122/	-0.20666	-3.42388	-3.63605	-0.20090	-7.46749
123/	-1.90892	-6.18782	-6.59615	-4.71605	-9.97684
124/	-0.472395	-0.80962	2.18108	19.58500	22.55174
125/	-1.97642	-0.32677	0.66141	-12.76401	14.20277
126/	-0.94237	-1.04408	1.52176	-12.71264	-10.57707
127/	-1.77582	-0.46897	-0.04275	-10.42732	-0.05392
128/	-1.93481	-0.25705	0.10523	-19.42737	-12.44842
129/	-0.45499	-0.07270	1.65020	-9.48960	-3.82812
130/	-0.50953	-0.20214	-1.41586	-6.79549	-5.44517
131/	-0.13661	-0.45691	-1.12895	1.68146	-0.64508
132/	-0.74069	-0.44572	-0.04330	-4.81474	-1.37482
133/	-0.14766	-0.02249	-0.04440	-0.59577	1.58217
134/	-0.94671	-1.05913	-0.09987	1.79808	1.46965
135/	-0.06943	-0.92690	0.36283	-4.60888	-6.13822
136/	-0.96526	-0.01390	-0.14369	-5.78289	-6.06767
137/	-0.15500	-0.45317	-0.10971	-0.98455	1.20669
138/	-0.07429	-0.35281	-0.04260	3.28965	2.64445
139/	-0.24979	-0.98867	-1.81267	-7.20813	-4.73523
140/	-0.03912	-1.68524	-1.43587	-5.10735	-1.76800
141/	-0.38722	-1.77959	-0.32975	-5.15133	-2.54845
142/	-0.15665	-1.75428	-0.35298	-4.64763	-2.40694
143/	-0.45804	-0.47064	-0.47080	0.34811	1.90544
144/	-0.45370	-1.53363	-0.34895	6.44820	3.99007
145/	-0.09031	-2.80577	-3.48983	-8.29230	-2.22789
146/	-0.05317	-3.10486	-1.48983	-5.32863	-0.68077
147/	-0.19305	-0.26648	-0.65251	0.35545	-0.15659
148/	-0.23547	-0.50148	-0.20905	1.30245	1.24549
149/	-0.80576	-1.01534	-0.63615	-0.95885	-1.49840
150/	0.81434	1.29230	-1.44119	-4.92852	-1.42630
151/	0.16347	0.35649	0.33131	0.0	1.05973
TOTALS	-11.24442	-13.13231	-5.12388	29.49049	-0.01010

SALT TRANSPORT AT 16 DEGREES SOUTH UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
121/	-16.49490	-5.94943	104.16962	0.0	81.72530
122/	-17.48506	-119.71475	-125.12486	-6.96609	-259.29175
123/	-70.40956	-216.94827	-227.07097	164.91350	-349.51489
124/	-15.70598	-28.26271	77.15009	498.05957	499.76636
125/	-13.45686	-36.64832	27.20386	410.63843	-371.71875
126/	-35.09483	-36.76996	57.24609	-430.64014	-371.71875
127/	-65.65259	-16.39355	17.97206	94.49612	-430.64014
128/	-71.55952	-15.08612	1.62513	353.10840	-430.64014
129/	-16.83340	-9.05764	3.62513	327.61670	-430.64014
130/	-18.67319	-2.58885	56.99352	-327.61670	-430.64014
131/	-27.43163	-6.98554	-48.92795	-1236.82222	-189.93423
132/	-4.94563	-15.65782	-38.92934	236.68941	-23.437085
133/	-27.43163	-15.65782	-38.92934	58.41873	-23.437085
134/	-71.55952	-36.64832	-1.54603	-20.42795	-51.226230
135/	-35.09483	-5.94943	-12.51715	160.77660	51.226230
136/	-70.40956	-216.94827	-227.07097	-201.37007	-212.26098
137/	-15.70598	-36.64832	27.20386	34.80618	56.70134
138/	-13.45686	-36.76996	57.24609	14.80618	91.04521
139/	-35.09483	-16.39355	17.97206	-217.91689	-61.03775
140/	-48.92795	-38.92934	-52.58248	-161.32211	-61.03775
141/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
142/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
143/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
144/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
145/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
146/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
147/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
148/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
149/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
150/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
151/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
152/	-38.92934	-52.58248	-52.58248	-161.32211	-61.03775
TOTALS	-413.63354	-461.25879	-176.45419	1029.91431	-21.43213

HEAT TRANSPORT AT 16 DEGREES SOUTH
(CAL/SEC) X E12

STATION NUMBERS	SURFACE	S-ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
1221/	133.06561	-48.30283	838.51172	0.0	657.14307
1222/	-160.19104	-972.33008	-1010.51782	-53.65146	-2096.69019
1223/	-565.82471	-17261.05420	-1330.21899	1355.22192	-2851.87573
1224/	-1226.15031	-229.58040	605.68164	15544.97266	-6224.08203
1225/	-1593.11646	-94.28375	218.57265	3224.70679	-3960.11182
1226/	-284.04517	-297.95532	461.56152	-3401.32446	-2925.85278
1227/	-528.43408	-133.06711	-144.99217	-745.10156	-61.39136
1228/	-574.96533	-122.37030	11.63899	-787.99976	-3473.69604
1229/	-135.36227	-173.30360	129.18327	-2595.45410	-2686.49585
1230/	-150.52507	-20.97781	457.19873	-1351.06372	-1065.36792
1231/	-239.89386	56.67981	391.87691	-1869.73850	-1494.67741
1232/	-220.30255	-129.35280	-33.85205	-1463.86314	-1399.58179
1233/	-243.88165	-127.10625	12.08117	-227.88989	-385.73511
1234/	-575.91455	-294.15918	-28.08545	1455.72095	385.30298
1235/	-20.83340	-44.45911	-100.59053	-1471.35547	402.04834
1236/	-245.85832	2.47534	-39.88348	-1596.66504	-1679.56812
1237/	-21.93256	129.63614	30.53033	272.43164	454.53052
1238/	-73.88785	-101.51631	-11.80711	907.68848	720.47705
1239/	-11.50390	-277.40063	-123.67358	-1988.45277	-1297.88257
1240/	-218.46025	-504.95938	-504.03931	-1684.80221	-454.72633
1241/	-113.95938	-277.94702	-121.42239	-1420.21021	-679.88159
1242/	-146.15223	-212.90662	-369.32861	1281.32819	652.94067
1243/	-146.50172	-135.47250	-147.37013	1776.19214	329.92778
1244/	-133.24199	-755.49683	-131.17007	1776.19214	1075.91724
1245/	-126.56766	-82.19507	-931.58521	-2287.09276	-1586.56860
1246/	-156.55540	-82.19507	-415.14380	14770.71948	157.72534
1247/	-56.97937	-75.74359	-180.88000	263.29126	-50.31152
1248/	-69.36746	-142.56670	-57.73219	359.86593	344.39893
1249/	-236.64766	-289.06006	-176.86743	264.62793	-437.94702
1250/	-239.61064	367.71851	-400.02539	-1363.85742	-1156.55371
1251/	48.34673	162.01459	92.00955	0.0	302.37085
TOTALS	-3328.71582	-3745.13647	-1424.19434	8131.60547	-366.43750

MASS TRANSPORT AT 24 DEGREES SOUTH
UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
416/ 418	0.48135	0.076649	0.01744	0.016686	0.48135
417/ 419	1.33561	-0.78394	-0.32553	2.165301	-4.28641
418/ 420	-2.00308	-0.25052	-0.13822	1.220068	-2.91973
419/ 421	0.10785	-0.96046	-0.31375	0.99558	2.82736
420/ 422	-0.55757	-0.67545	-0.18551	5.64439	4.15592
421/ 423	-0.62353	-0.88382	-0.16376	-0.91304	0.80362
422/ 424	0.66909	0.13493	0.07968	0.23319	0.57400
423/ 425	-0.12620	-0.63338	-0.27624	1.13080	-0.22947
424/ 426	-0.42064	-0.66333	-0.11173	3.49478	-2.12378
425/ 427	-0.16609	-0.15093	0.22149	-4.58800	-1.79252
426/ 428	-0.94709	1.09620	0.42142	3.31584	-0.41866
427/ 429	-2.70515	-1.07433	-0.22028	-3.87158	-0.31193
428/ 430	0.22999	-0.62766	-0.03722	-2.06425	-0.43235
429/ 431	0.02335	-0.30829	-0.04077	-0.57722	-1.15984
430/ 432	0.60635	0.02214	0.08271	1.30338	-5.73506
431/ 433	0.40711	3.32220	-0.13213	1.19138	3.22553
432/ 434	1.42182	-0.18416	-0.02429	1.90138	-4.60521
433/ 435	-0.27171	-5.52562	-0.15096	1.41958	-1.52643
434/ 436	-2.59147	-0.09115	-0.10722	-4.19588	-4.26439
435/ 437	0.20071	-0.51247	-0.07733	1.03952	-1.57745
436/ 438	-0.27849	-0.02347	-0.22155	-6.02291	-2.60589
437/ 439	-0.73001	-0.70768	-0.64559	3.02291	-1.47152
438/ 440	-0.29948	-0.85861	-0.37159	-0.17465	-2.35369
439/ 441	-0.15835	-1.00896	-0.13404	-2.74655	-3.53551
440/ 442	-0.14691	-0.04667	-0.43742	5.97932	10.51734
441/ 443	-0.19728	-1.25529	-0.03219	-5.03234	-5.60145
442/ 444	-0.06810	-2.47724	-0.58786	0.67406	1.16572
443/ 445	-0.20243	-0.44340	-0.06473	0.14822	-1.92137
444/ 446	0.02529	-0.80348	-0.08537	0.91778	-1.47441
445/ 447	0.00000	-0.24264	-0.08537	-5.12115	-4.08839
446/ 448	0.00000	-4.46066	-0.38563	1.06740	-4.56066
447/ 449	0.00000	-2.24921	-0.06473	0.14822	-1.92137
448/ 450	0.00000	-2.05579	-0.20882	0.91778	-1.47441
449/ 451	0.00000	-1.67567	-0.07655	-5.60075	-4.56066
450/ 452	0.00000	-0.47842	-0.09220	-1.33293	-4.96706
451/ 453	0.00000	-0.02970	-0.81103	-5.60803	-0.12294
452/ 454	0.00000	-0.95198	-0.60039	-1.22122	-0.03098
453/ 455	0.00000	-0.48937	-0.60039	0.00000	-0.03463
454/ 456	0.00000	-0.03098	0.00000	0.00000	-0.02672
455/ 457	0.00000	-0.34631	0.00000	0.00000	-0.02672
456/ 458	-3.40335	-16.98189	-1.99157	22.35007	-0.02672
TOTALS					

SALT TRANSPORT AT 24 DEGREES SOUTH
UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
416/ 417	17.60094	0.0	0.0	0.0	17.60094
417/ 418	48.32596	27.22797	0.73153	75.43556	152.33101
418/ 419	-73.32178	-62.52258	-1.17383	57.72702	-89.69116
419/ 420	3.96438	-8.74070	1.75003	76.87279	67.34644
420/ 421	20.36931	33.70891	10.78915	34.79819	99.66554
421/ 422	-22.74612	-31.07333	-6.34861	197.03711	142.21527
422/ 423	24.40808	31.07333	5.61719	31.83580	29.26280
423/ 424	4.58080	4.75990	2.74747	3.25204	20.34015
424/ 425	-15.30823	-23.32878	-9.50276	39.42769	-8.71207
425/ 426	6.04934	5.33453	3.84947	32.52577	137.34821
426/ 427	34.63931	38.60097	10.01576	155.83717	-72.26968
427/ 428	-25.78371	-35.68939	-10.49388	-115.12561	-39.44498
428/ 429	-80.89262	-72.96606	-10.71191	-198.86214	-13.80965
429/ 430	16.40399	22.08251	7.56500	59.25063	-10.86466
430/ 431	0.86260	-10.82203	-1.30110	-0.57392	-10.10504
431/ 432	22.13593	30.13355	0.61247	54.55308	-40.68050
432/ 433	14.87630	0.79108	-1.41686	-389.65388	-192.77150
433/ 434	15.65364	116.62951	23.43565	45.58588	226.25047
434/ 435	-9.87055	-6.33850	-0.88293	10.73004	178.83446
435/ 436	-93.56217	-194.32801	-38.74586	66.24622	-160.48158
436/ 437	10.56210	18.00699	-1.51945	143.24622	-14.57280
437/ 438	17.29107	-0.87731	2.65622	37.01019	194.05502
438/ 439	-10.11004	-24.09591	-2.18008	10.83195	-62.02089
439/ 440	-26.46388	-30.01860	-2.77644	195.53114	-164.79663
440/ 441	-10.83243	-35.36064	-12.32582	175.50022	-1365.64600
441/ 442	5.70635	1.90761	6.04726	10.77789	-85.79663
442/ 443	-5.29234	-43.90761	15.04726	175.50022	-1365.64600
443/ 444	-7.44672	-14.08466	-20.41766	383.69906	-298.47070
444/ 445	-5.16754	-87.08459	-20.43073	178.62202	194.99275
445/ 446	3.1878	28.48268	19.93658	178.62202	194.99275
446/ 447	7.90328	-8.52919	13.26471	23.84742	17.37985
447/ 448	-0.0	5.04076	13.26471	35.15761	55.04324
448/ 449	0.0	-149.57614	-36.18282	11.95441	-187.55505
449/ 450	0.0	-72.32664	-7.18282	11.95441	-67.46368
450/ 451	0.0	-58.80598	-24.66299	13.00353	-58.03868
451/ 452	0.0	-16.78940	-0.31797	20.93122	-152.52675
452/ 453	0.0	-1.13168	-27.62472	195.61696	-172.91946
453/ 454	0.0	-33.42223	10.72006	-42.0.0	-12.47032
454/ 455	0.0	-16.99942	0.0	0.0	-12.47032
455/ 456	0.0	-1.10130	0.0	0.0	-12.47032
456/ 457	0.0	-12.12338	0.0	0.0	-12.47032
TOTALS	-122.69826	-597.16504	-68.17680	779.98511	-8.05493

HEAT TRANSPORT AT 24 DEGREES SOUTH (CAL/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
416/	141.85873	0.0	0.0	0.0	141.85873
417/	393.01587	220.91554	4.5894	599.22705	1273.40460
418/	-590.01587	-510.75342	-90.59940	457.22705	-1733.414139
419/	31.85185	-271.03339	-38.45643	608.27956	-531.17139
420/	164.03520	273.78296	-87.30933	275.26172	800.38916
421/	-183.34219	-192.69662	-51.77365	1557.77613	1229.96387
422/	196.75793	252.43646	45.60780	-2251.92633	1224.2354311
423/	-136.96672	38.64598	22.13287	311.20508	178.75220
424/	-123.51431	-189.49234	-76.79199	965.86768	-1088.75220
425/	148.75931	43.30463	30.82079	-1214.90210	-556.064770
426/	278.53931	313.93506	81.33686	229.49021	-556.23560
427/	-207.36304	-289.93722	-117.36864	774.96558	-556.23560
428/	-651.38496	-592.89722	-86.51677	-472.58047	-100.362206
429/	132.10126	179.35757	61.15977	-10.28876	-87.767129
430/	6.91063	-87.94823	10.28876	-4.45336	413.352231
431/	178.07684	244.71568	-4.27788	-4.45336	413.352231
432/	119.62230	949.07275	230.62204	-3079.73535	-1482.90741
433/	416.37842	-53.75102	6.31909	3558.09033	905.47998
434/	-758.78666	-1579.25586	-514.34228	5527.60571	-273.011729
435/	58.90500	26.68149	-21.24256	-128.67456	1354.43779
436/	-81.67590	-7.12604	21.53563	188.08894	1525.485107
437/	-213.55025	203.98799	-21.40488	-875.25539	-1312.198224
438/	137.22054	-247.48730	179.23591	75.25539	-1312.198224
439/	-46.96507	-113.32710	103.15622	-1387.62640	-676.15903
440/	47.64406	317.08252	121.59521	-1387.62640	-676.15903
441/	-57.85710	-708.25030	-163.50920	-1024.22933	-2389.57983
442/	59.58835	231.65009	166.78642	1442.06958	1546.521279
443/	-0.0	-69.40044	23.63605	240.22783	135.293379
444/	0.0	40.95065	107.74277	94.86038	144.40918
445/	0.0	217.59570	295.17814	255.37944	552.44116
446/	0.0	589.12769	58.17427	-1416.09473	-425.07275
447/	0.0	-479.26416	-199.18843	255.37944	-425.07275
448/	0.0	-136.93535	-22.58561	-1416.09473	-1202.93188
449/	0.0	-9.07568	86.50745	-1533.556	-12561.20728
450/	0.0	137.98619	167.15346	0.0	-12561.20728
451/	0.0	-9.15942	0.0	0.0	-9.15942
452/	0.0	-99.15234	0.0	0.0	-99.15234
453/	-993.78101	-4861.37500	-554.42651	6170.85547	-238.72266
TOTALS					

MASS TRANSPORT AT 32 DEGREES SOUTH UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BCITCM	STATION TOTAL
5806/5807	0.02668	0.01883	0.58216	0.0	0.04551
5807/5808	0.39893	-0.86446	-7.94696	0.0	-8.04768
5808/5809	1.77983	-2.38966	-2.20091	-7.51285	-6.69037
5809/5810	-1.51176	-1.88529	-0.31133	14.98032	-1.91173
5810/5811	-0.51836	-0.59057	-0.49863	-2.26465	1.40058
5811/5812	-0.28072	-0.42492	-0.20423	9.43033	1.62176
5812/5813	-0.86491	-1.53829	-0.37578	-3.17673	1.83136
5813/5814	-0.46759	-1.89738	-0.34839	4.12490	1.48895
5814/5815	0.48657	1.33594	0.65624	-1.02490	5.59144
5815/5816	0.47347	1.36234	-0.85466	0.56105	5.51370
5816/5817	-1.25774	-3.73030	-0.40479	1.33746	-4.02807
5817/5818	-0.17430	-0.52182	0.56377	-6.17936	-0.02807
5818/5819	0.90245	-0.15775	0.17997	1.42773	1.91327
5819/5820	0.14872	-0.18155	-0.45299	-3.55218	-3.59867
5820/5821	-0.82534	-0.84222	-0.19077	-1.55218	-0.08477
5821/5822	-0.09310	-0.91958	-0.26407	1.55111	1.25850
5822/5823	-0.56934	-1.53867	-0.35179	4.86308	1.47486
5823/5824	-0.59515	-1.62740	-0.47668	1.02213	-2.33036
5824/5825	-0.48331	-2.00408	-0.43422	-0.62134	-2.62035
5825/5826	-0.80937	-2.54184	-0.13471	-3.51459	-1.02133
5826/5827	-0.36868	-2.20180	-0.35071	0.51459	2.62034
5827/5828	-0.74279	-0.27116	-0.03483	-1.87353	-0.60988
5828/5829	-0.75966	-1.36039	-0.43526	-4.43976	-0.31762
5829/5830	-2.48536	-5.51403	-1.79522	-4.43976	7.81468
5830/5831	-1.72282	-5.73637	-0.24518	-3.54718	-3.12165
5831/5832	-0.43550	-0.45785	-0.18615	-6.53968	-7.52630
5832/5833	0.0	-11.75444	-1.99507	-10.56445	-2.18506
5833/5834	0.0	-13.51068	-1.05468	4.10130	5.91479
5834/5835	0.0	10.54868	0.45063	6.10130	17.05269
5835/5836	0.0	-21.83522	-2.60639	13.56528	-8.78525
5836/5837	0.0	-1.01260	-0.02469	-2.19850	17.80854
5837/5838	0.0	-5.21178	-2.03801	0.0	10.23579
5838/5839	0.0	-2.52367	-0.77254	0.0	3.59192
5839/5840	0.0	-0.17870	0.0	0.0	3.29621
5840/5841	0.0	-0.37305	0.0	0.0	-0.17870
TOTALS	-0.85776	-25.17276	-16.78152	42.82959	0.01755

HEAT TRANSPORT AT 32 DEGREES SOUTH UNITS ARE (CAL/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
5806/5807	7.89299	5.45182	0.0	0.0	13.34481
5807/5808	116.81583	-239.16728	-2107.31152	0.0	-229.96284
5808/5809	116.80273	-682.69702	-813.21094	-2186.94620	-1794.65747
5809/5810	11522.48584	-539.80811	-853.36559	-4266.94653	-3241.58775
5810/5811	11522.32939	-455.48569	-866.22642	-2222.65063	-445.47363
5811/5812	11522.45547	-121.11714	-138.51523	2598.38013	1844.34082
5812/5813	11522.95515	-555.11759	-555.79169	1152.00635	381.97607
5813/5814	1137.07677	-528.39673	-104.78795	-876.64997	3205.32007
5814/5815	260.50415	655.33598	134.41635	282.75958	-1304.48706
5815/5816	139.32363	524.85034	182.31688	264.79852	-276.13748
5816/5817	50.98161	-962.35229	-237.61488	368.21772	-991.94727
5817/5818	2.38037	-2006.02856	-112.75267	-1704.11428	-61.22315
5818/5819	43.38032	-643.85400	-149.83173	950.06885	-871.13574
5819/5820	17.22727	-240.35817	-154.57797	-549.05762	1339.88501
5820/5821	126.69495	-544.30683	-73.94905	1583.51562	-667.86504
5821/5822	173.41747	-554.78491	-57.94961	5171.38305	-759.12399
5822/5823	141.71936	-573.09528	-120.82130	-1571.82515	-471.43994
5823/5824	2307.76987	-170.94507	-99.64769	-1155.80224	151.50317
5824/5825	163.75444	-192.32199	-5.58678	-457.99243	60.71289
5825/5826	122.76534	-388.62085	-221.09924	-791.49854	2321.0518
5826/5827	122.76534	-243.62085	-469.50903	-1307.44331	-1846.23218
5827/5828	122.76534	-164.62085	-221.39642	-1273.33279	-2085.67525
5828/5829	122.76534	-130.66617	-51.40305	-1762.45996	-1233.58434
5829/5830	122.76534	-387.90964	-254.26172	-2932.18470	2258.66431
5830/5831	122.76534	-370.90964	-125.48276	1914.23901	5030.62036
5831/5832	122.76534	-1019.36694	-125.17450	1914.23901	-3242.83154
5832/5833	122.76534	-6277.53422	-726.41821	3757.25297	-2145.34912
5833/5834	122.76534	-1485.10742	-660.66748	-60.000	-1934.77490
5834/5835	122.76534	-1719.53125	-214.81793	0.0	-51.19756
5835/5836	122.76534	-106.97672	0.0	0.0	-106.97672
5836/5837	122.76534	-106.97672	0.0	0.0	-106.97672
5837/5838	122.76534	-106.97672	0.0	0.0	-106.97672
5838/5839	122.76534	-106.97672	0.0	0.0	-106.97672
5839/5840	122.76534	-106.97672	0.0	0.0	-106.97672
5840/5841	122.76534	-106.97672	0.0	0.0	-106.97672
5841/5842	122.76534	-106.97672	0.0	0.0	-106.97672
5842/5843	122.76534	-106.97672	0.0	0.0	-106.97672
5843/5844	122.76534	-106.97672	0.0	0.0	-106.97672
5844/5845	122.76534	-106.97672	0.0	0.0	-106.97672
5845/5846	122.76534	-106.97672	0.0	0.0	-106.97672
5846/5847	122.76534	-106.97672	0.0	0.0	-106.97672
5847/5848	122.76534	-106.97672	0.0	0.0	-106.97672
5848/5849	122.76534	-106.97672	0.0	0.0	-106.97672
5849/5850	122.76534	-106.97672	0.0	0.0	-106.97672
5850/5851	122.76534	-106.97672	0.0	0.0	-106.97672
5851/5852	122.76534	-106.97672	0.0	0.0	-106.97672
5852/5853	122.76534	-106.97672	0.0	0.0	-106.97672
5853/5854	122.76534	-106.97672	0.0	0.0	-106.97672
5854/5855	122.76534	-106.97672	0.0	0.0	-106.97672
5855/5856	122.76534	-106.97672	0.0	0.0	-106.97672
5856/5857	122.76534	-106.97672	0.0	0.0	-106.97672
5857/5858	122.76534	-106.97672	0.0	0.0	-106.97672
5858/5859	122.76534	-106.97672	0.0	0.0	-106.97672
5859/5860	122.76534	-106.97672	0.0	0.0	-106.97672
5860/5861	122.76534	-106.97672	0.0	0.0	-106.97672
5861/5862	122.76534	-106.97672	0.0	0.0	-106.97672
5862/5863	122.76534	-106.97672	0.0	0.0	-106.97672
5863/5864	122.76534	-106.97672	0.0	0.0	-106.97672
5864/5865	122.76534	-106.97672	0.0	0.0	-106.97672
5865/5866	122.76534	-106.97672	0.0	0.0	-106.97672
5866/5867	122.76534	-106.97672	0.0	0.0	-106.97672
5867/5868	122.76534	-106.97672	0.0	0.0	-106.97672
5868/5869	122.76534	-106.97672	0.0	0.0	-106.97672
5869/5870	122.76534	-106.97672	0.0	0.0	-106.97672
5870/5871	122.76534	-106.97672	0.0	0.0	-106.97672
5871/5872	122.76534	-106.97672	0.0	0.0	-106.97672
5872/5873	122.76534	-106.97672	0.0	0.0	-106.97672
5873/5874	122.76534	-106.97672	0.0	0.0	-106.97672
5874/5875	122.76534	-106.97672	0.0	0.0	-106.97672
5875/5876	122.76534	-106.97672	0.0	0.0	-106.97672
5876/5877	122.76534	-106.97672	0.0	0.0	-106.97672
5877/5878	122.76534	-106.97672	0.0	0.0	-106.97672
5878/5879	122.76534	-106.97672	0.0	0.0	-106.97672
5879/5880	122.76534	-106.97672	0.0	0.0	-106.97672
5880/5881	122.76534	-106.97672	0.0	0.0	-106.97672
5881/5882	122.76534	-106.97672	0.0	0.0	-106.97672
5882/5883	122.76534	-106.97672	0.0	0.0	-106.97672
5883/5884	122.76534	-106.97672	0.0	0.0	-106.97672
5884/5885	122.76534	-106.97672	0.0	0.0	-106.97672
5885/5886	122.76534	-106.97672	0.0	0.0	-106.97672
5886/5887	122.76534	-106.97672	0.0	0.0	-106.97672
5887/5888	122.76534	-106.97672	0.0	0.0	-106.97672
5888/5889	122.76534	-106.97672	0.0	0.0	-106.97672
5889/5890	122.76534	-106.97672	0.0	0.0	-106.97672
5890/5891	122.76534	-106.97672	0.0	0.0	-106.97672
5891/5892	122.76534	-106.97672	0.0	0.0	-106.97672
5892/5893	122.76534	-106.97672	0.0	0.0	-106.97672
5893/5894	122.76534	-106.97672	0.0	0.0	-106.97672
5894/5895	122.76534	-106.97672	0.0	0.0	-106.97672
5895/5896	122.76534	-106.97672	0.0	0.0	-106.97672
5896/5897	122.76534	-106.97672	0.0	0.0	-106.97672
5897/5898	122.76534	-106.97672	0.0	0.0	-106.97672
5898/5899	122.76534	-106.97672	0.0	0.0	-106.97672
5899/5900	122.76534	-106.97672	0.0	0.0	-106.97672
TOTALS	-250.10114	-7184.11323	-4663.28906	11759.19141	-258.30859

SALT TRANSPORT AT 32 DEGREES SOUTH
UNITS ARE (GRAMS/SEC) X E12

STATION NUMBERS	SURFACE	S. ATLANTIC CENTRAL	ANTARCTIC INTERMED	DEEP AND BOTTOM	STATION TOTAL
55806/5807	0.94697	0.67367	0.0	0.0	1.62064
55807/5808	14.41425	-25.38832	-260.27417	0.0	-275.24805
55808/5809	64.55176	-84.15514	-101.71237	-274.70801	-227.13495
55809/5810	-47.40367	-66.15585	7.24112	-520.15234	-419.43286
55810/5811	-18.58302	-56.07300	-10.64452	-378.79909	-156.30563
55811/5812	-10.04528	-68.91847	-17.12022	328.60425	236.59547
55812/5813	-30.96237	-65.11729	-12.81104	145.67914	21.87398
55813/5814	-16.75739	-84.35919	-16.51811	-113.3	139.29083
55814/5815	16.92403	64.58821	-22.55333	110.57381	0.35337
55815/5816	-4.85979	-18.58877	-29.38478	46.61902	-40.18488
55816/5817	-6.20685	-125.91728	-15.19661	66.46355	-125.04685
55817/5818	-32.18280	-25.52607	-15.19661	-219.45717	-109.11567
55818/5819	5.31400	-76.81383	-15.76785	119.44020	53.38918
55819/5820	-25.43359	-29.59402	-8.98991	-65.43067	-92.74356
55820/5821	-21.18558	-68.17140	-12.05317	68.54073	-58.45398
55821/5822	-17.25653	-57.19650	-14.88324	-215.62999	-20.54224
55822/5823	-18.99538	-70.50047	-14.60145	215.62999	10.30589
55823/5824	-13.20458	-27.92128	-12.20793	-122.95272	-20.54224
55824/5825	-27.00890	-77.62344	-11.19801	105.15331	107.84277
55825/5826	-27.14435	-29.72336	-14.84822	-165.47353	-135.60508
55826/5827	-88.77379	-201.63470	-57.82908	-154.40042	-107.84277
55827/5828	-15.68396	-16.25617	-27.38248	-122.77331	-262.77334
55828/5829	0.0	-14.29297	-34.11153	-370.87393	-80.67154
55829/5830	0.0	-475.60938	-36.07991	122.77331	1281.87744
55830/5831	0.0	-125.11622	-15.51948	142.53875	64.1660
55831/5832	0.0	-366.33105	-89.62100	477.53875	6385.79492
55832/5833	0.0	-769.50725	-81.80940	477.53875	112.95588
55833/5834	0.0	-182.31944	-26.56882	0.0	-214.88965
55834/5835	0.0	-6.27320	0.0	0.0	-114.88965
55835/5836	0.0	-13.08676	0.0	0.0	-13.08676
55836/5837	0.0	-881.97144	-576.14258	1494.25366	6.21606
55837/5838	-29.92361	-881.97144	-576.14258	1494.25366	6.21606
55838/5839					
55839/5840					
55840/5841					
55841/5842					
55842/5843					
55843/5844					
55844/5845					
55845/5846					
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55980/5981					
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55987/5988					
55988/5989					
55989/5990					
55990/5991					
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55995/5996					
55996/5997					
55997/5998					
55998/5999					
55999/6000					

APPENDIX B

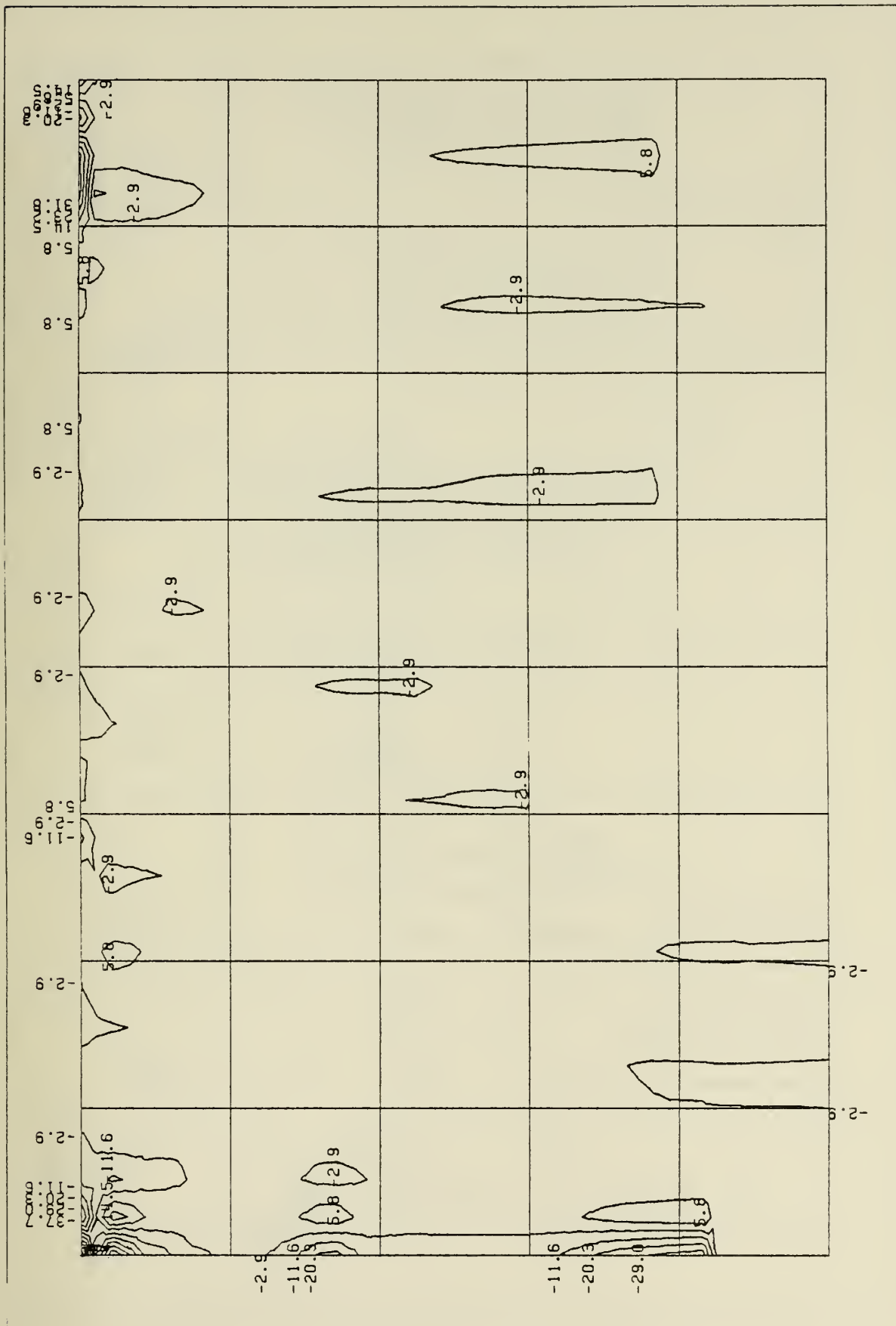
VERTICAL CROSS SECTIONS

Appendix B illustrates vertical cross sections of velocity, and transports of mass, salt, and heat for each latitude. These data were first interpolated to a rectangular grid covering the cross section by a computer subroutine named IBCIEU and then contoured by a subroutine named CONTUR. In executing CONTUR, the data field was first scanned for the highest and lowest values and then contour levels were drawn between them at thirteen intervals. The central values of maxima or minima were labeled, as were exterior contour segments. Since the contour intervals are determined by a data scan in each case, they are not identical for each chart but can be determined from the labels.

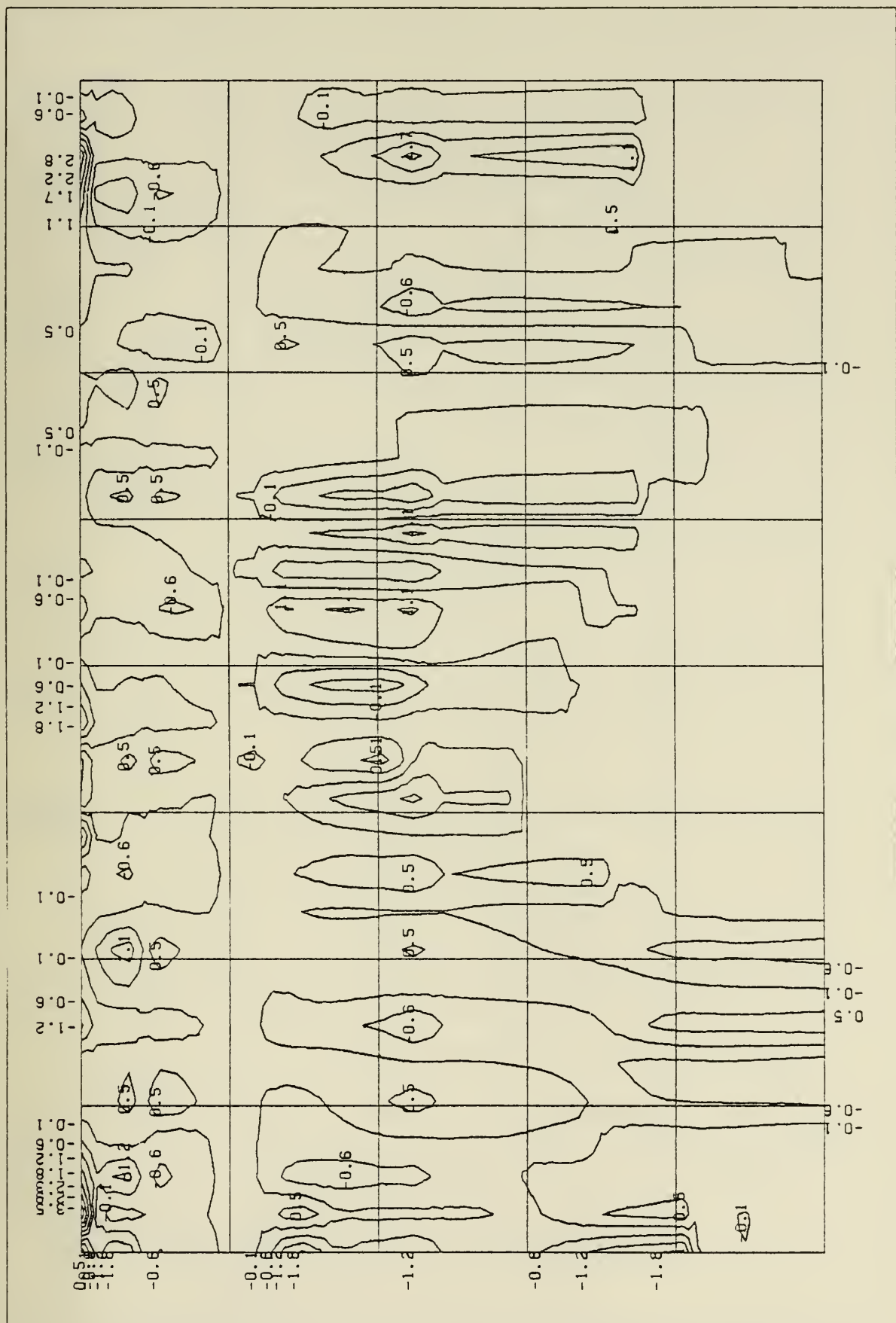
The one-inch grid superimposed on the diagrams represents depths in the vertical of 50, 1084, 2118, 3152, 4186, and 5220 meters for every chart. However, the horizontal extent represents the length of the ship's track and is different for each latitude. The values in kilometers per inch for 8°S, 16°S, 24°S, and 32°S are 163, 290, 314, and 169 respectively.

Units are: velocity, cm/sec; mass transport, gm/sec $\times 10^2$; salt transport, gm/sec $\times 10^9$; and heat transport, cal/sec $\times 10^9$.

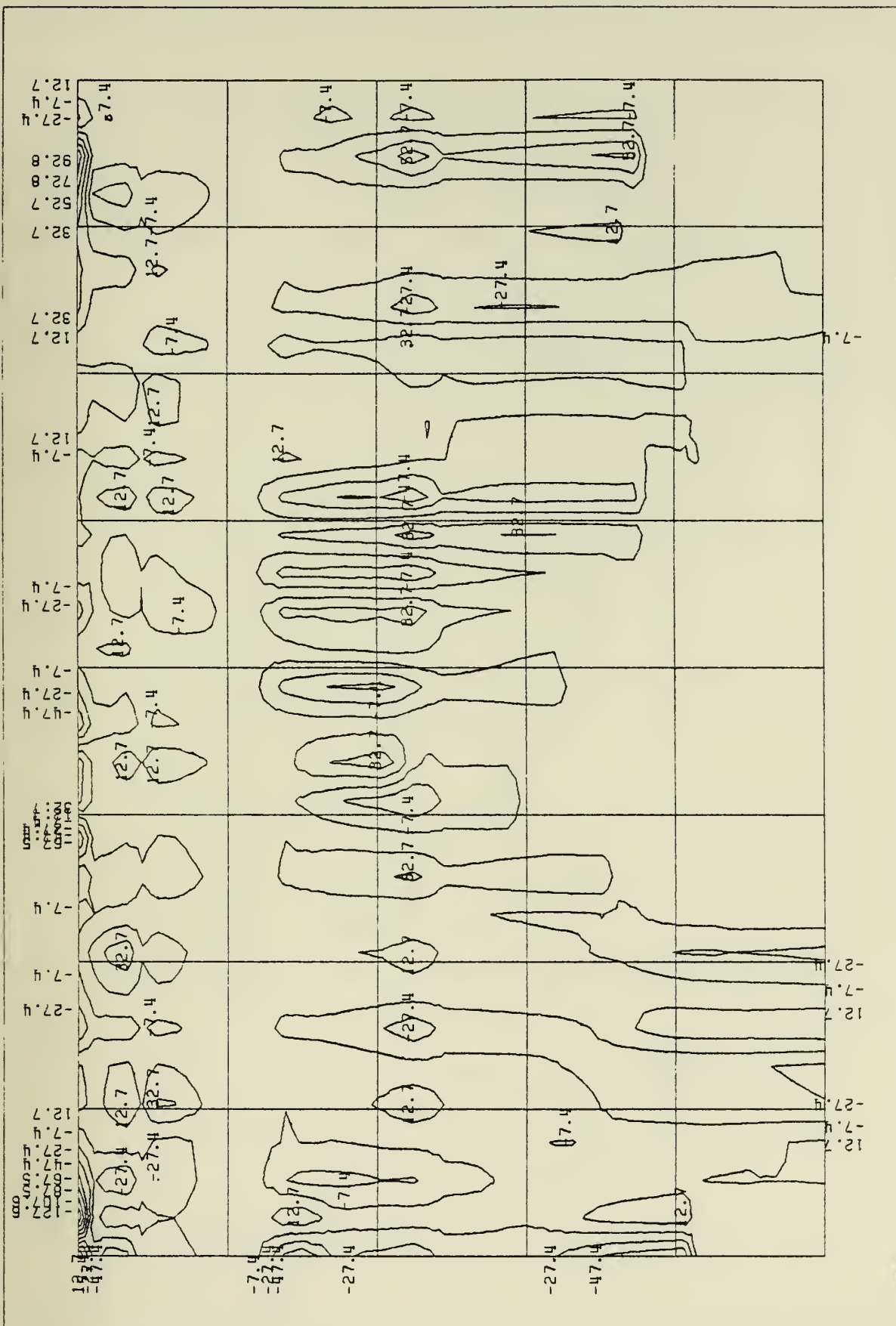
Negative values indicate northward transports.

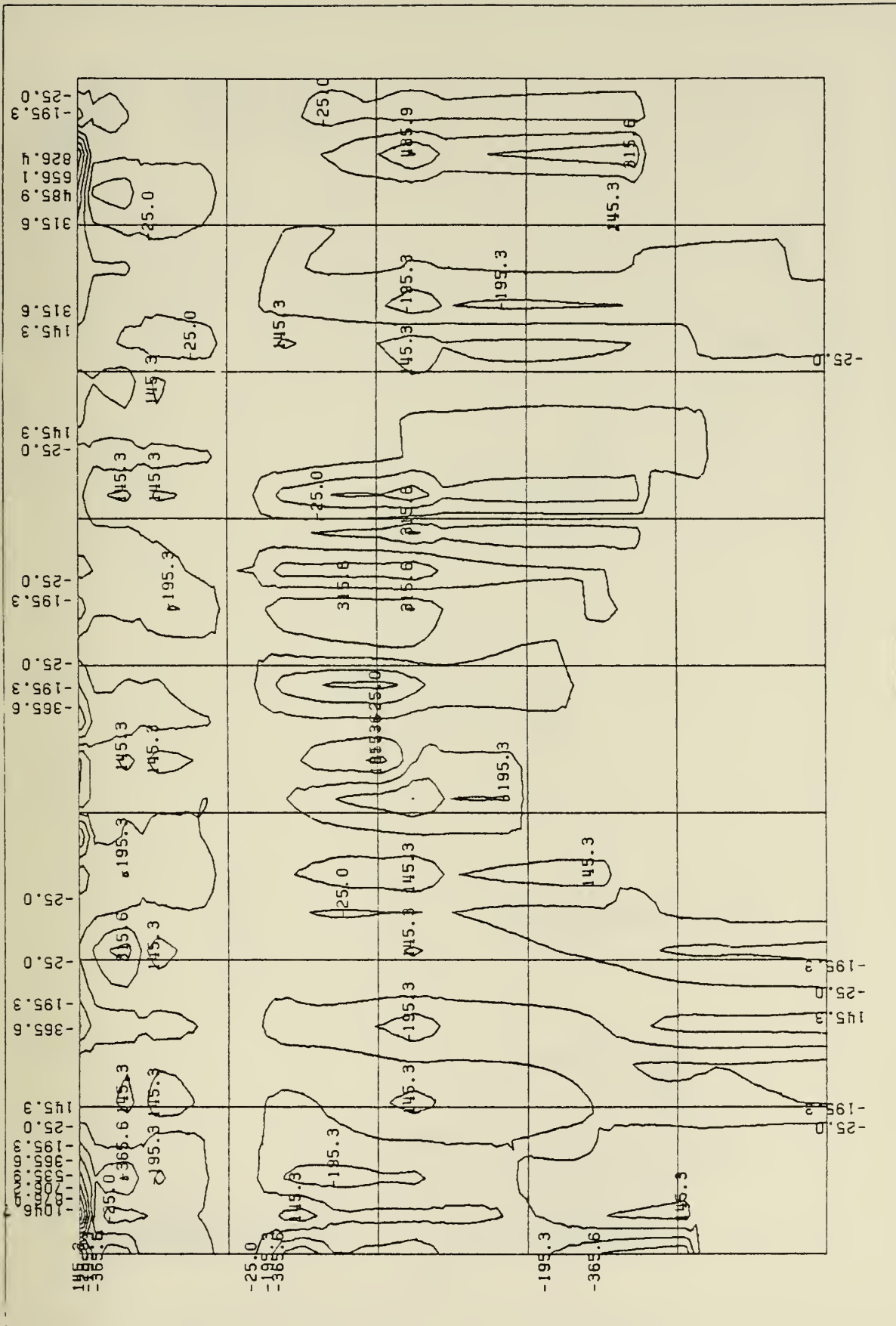


8°S VELOCITY

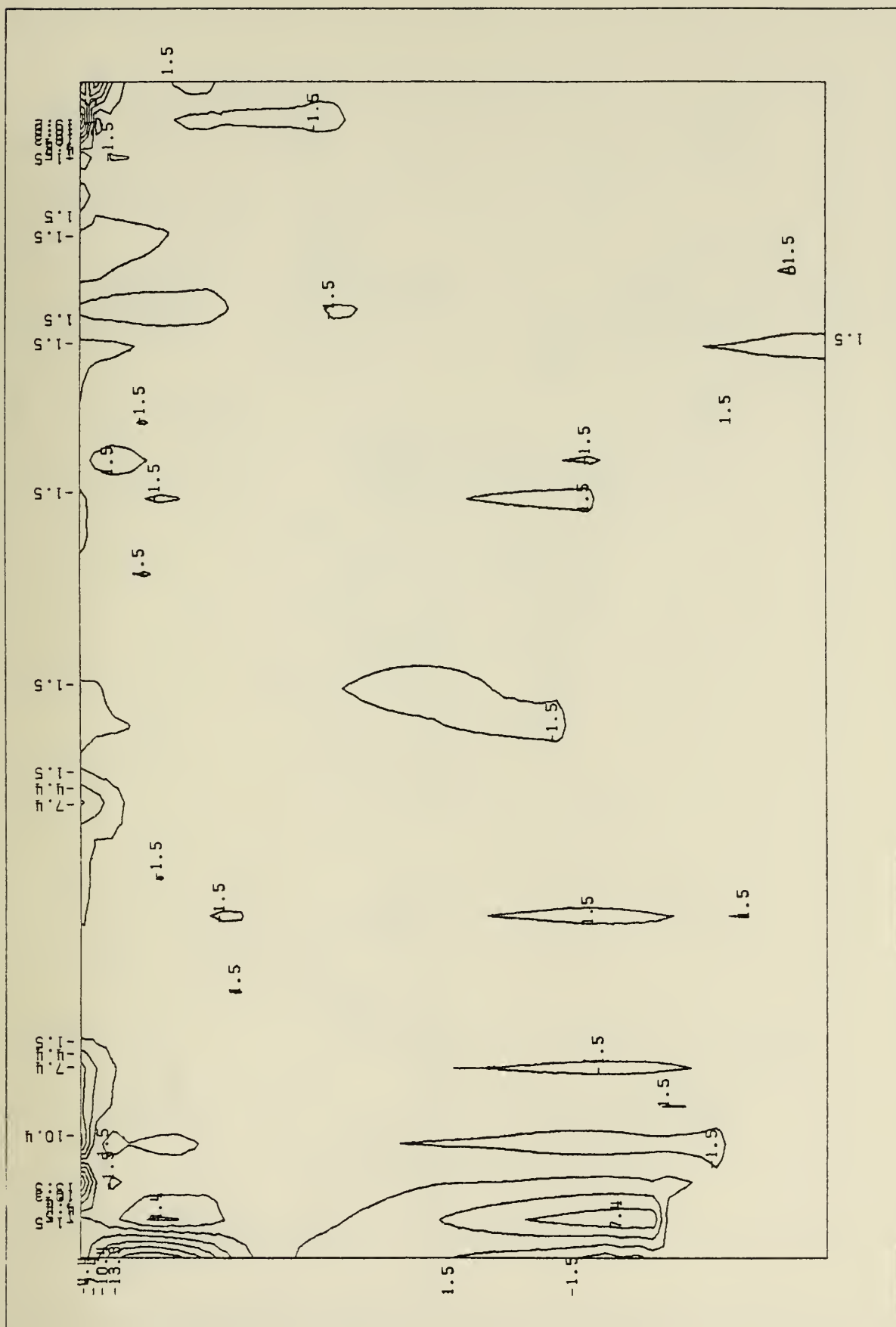


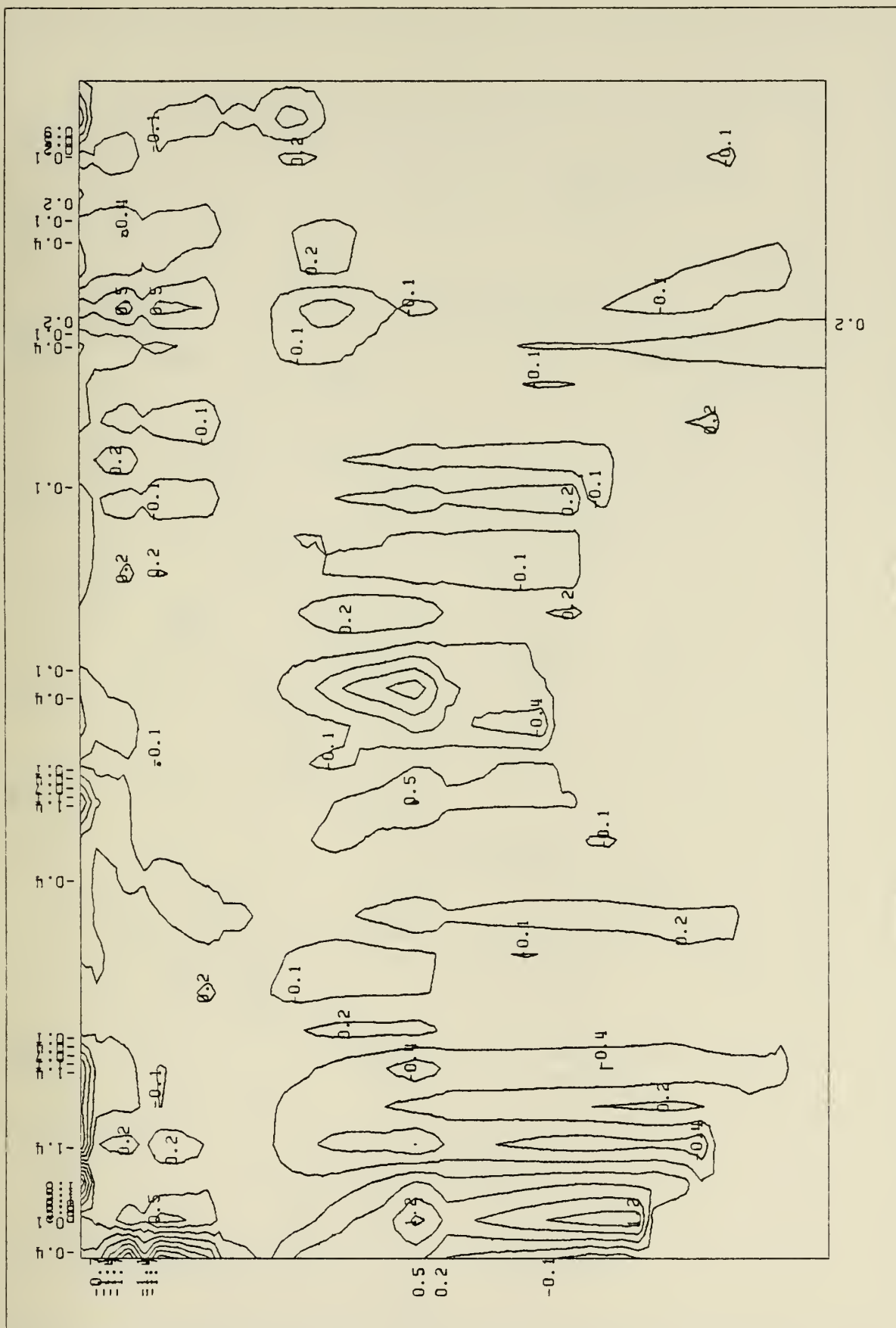
8°S MASS TRANSPORT



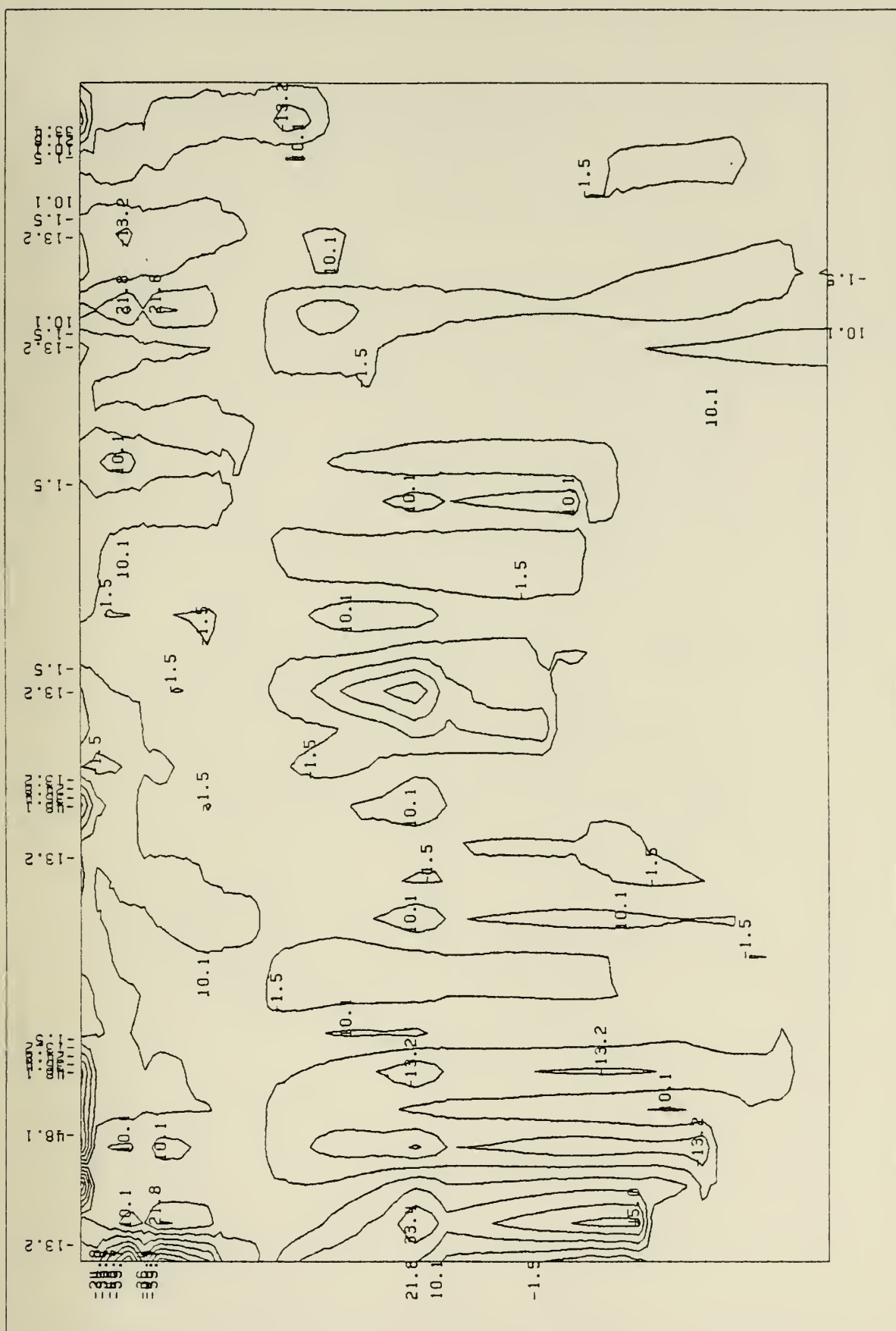


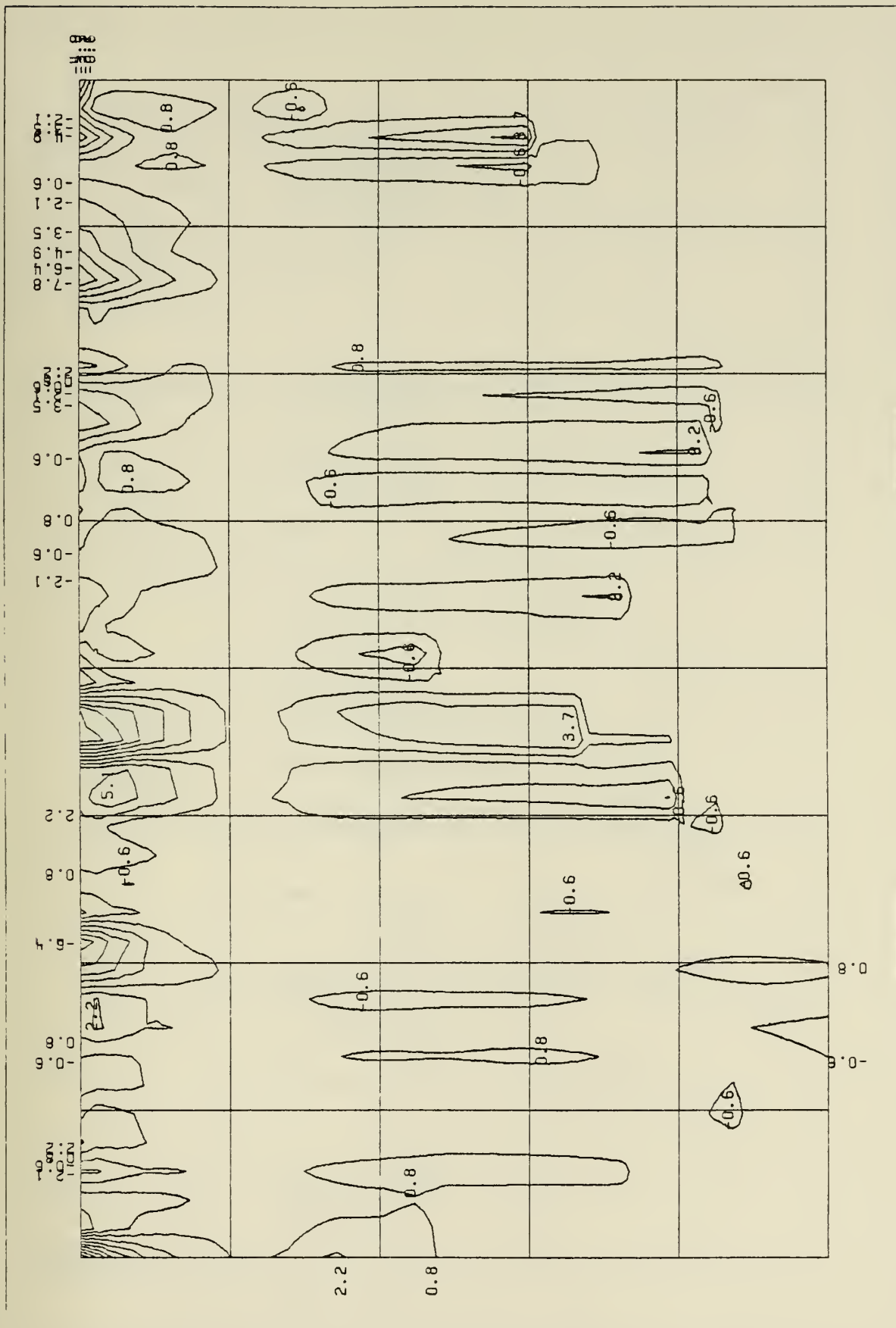
8°S HEAT TRANSPORT

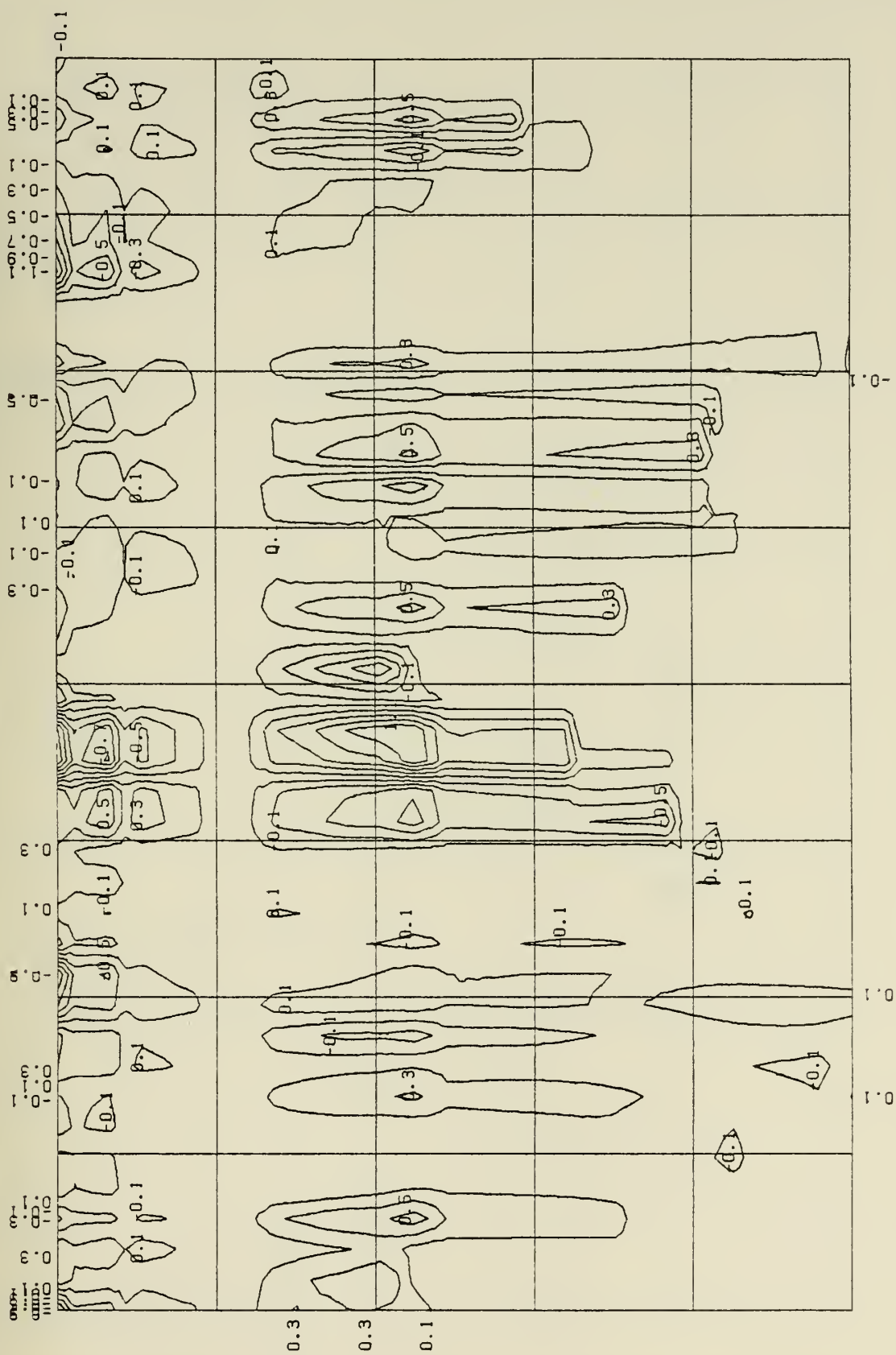




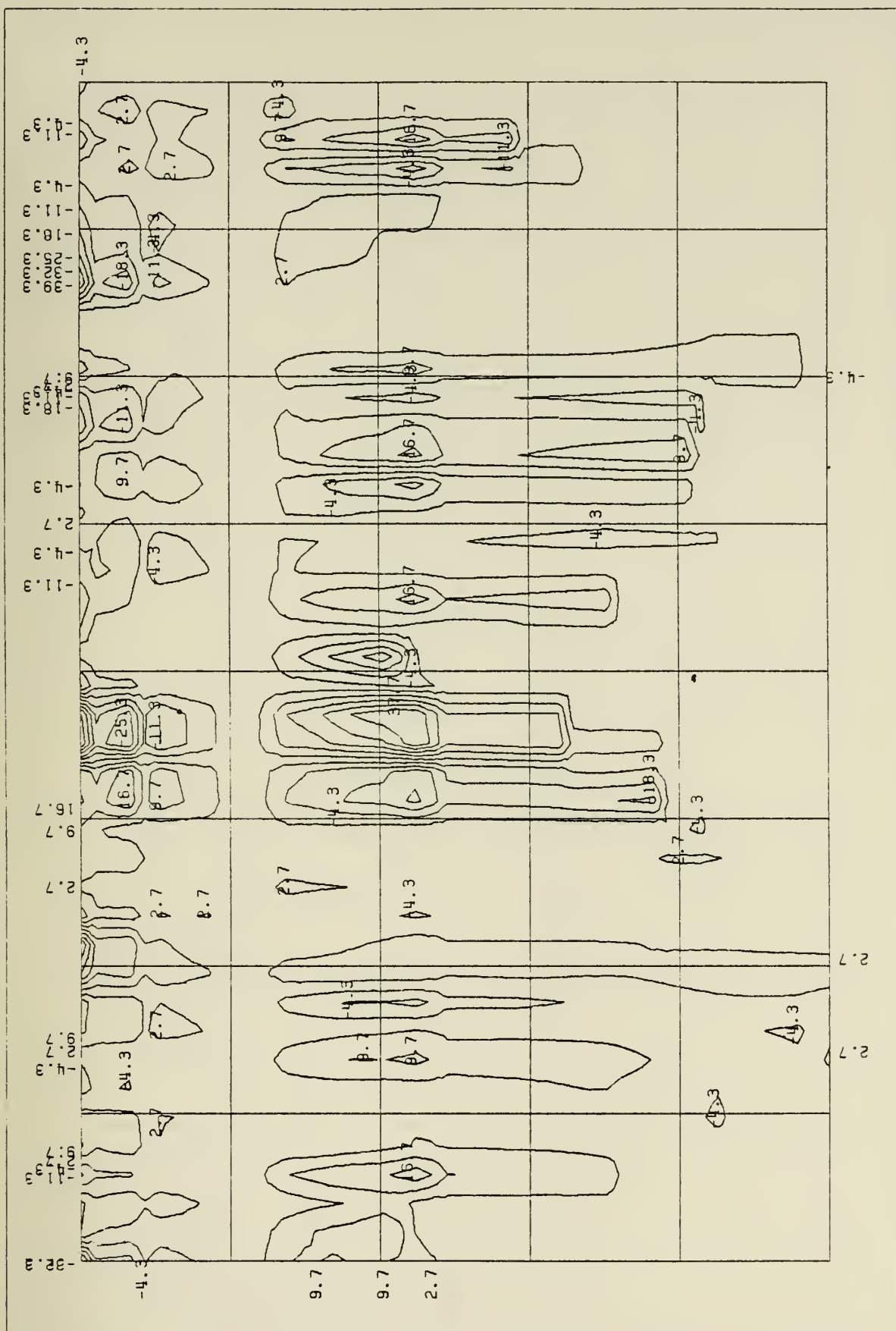
16°S MASS TRANSPORT





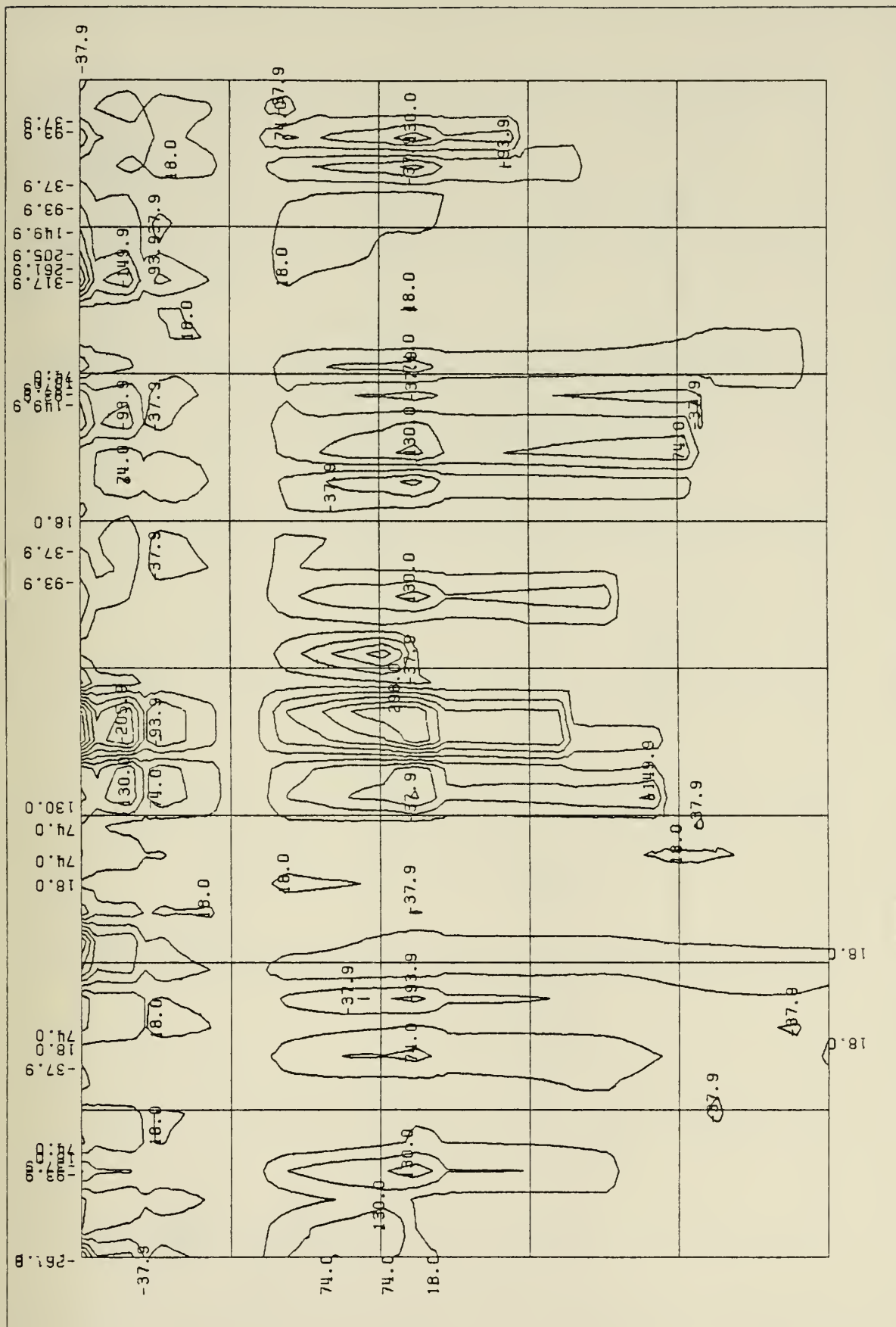


24° MASS TRANSPORT

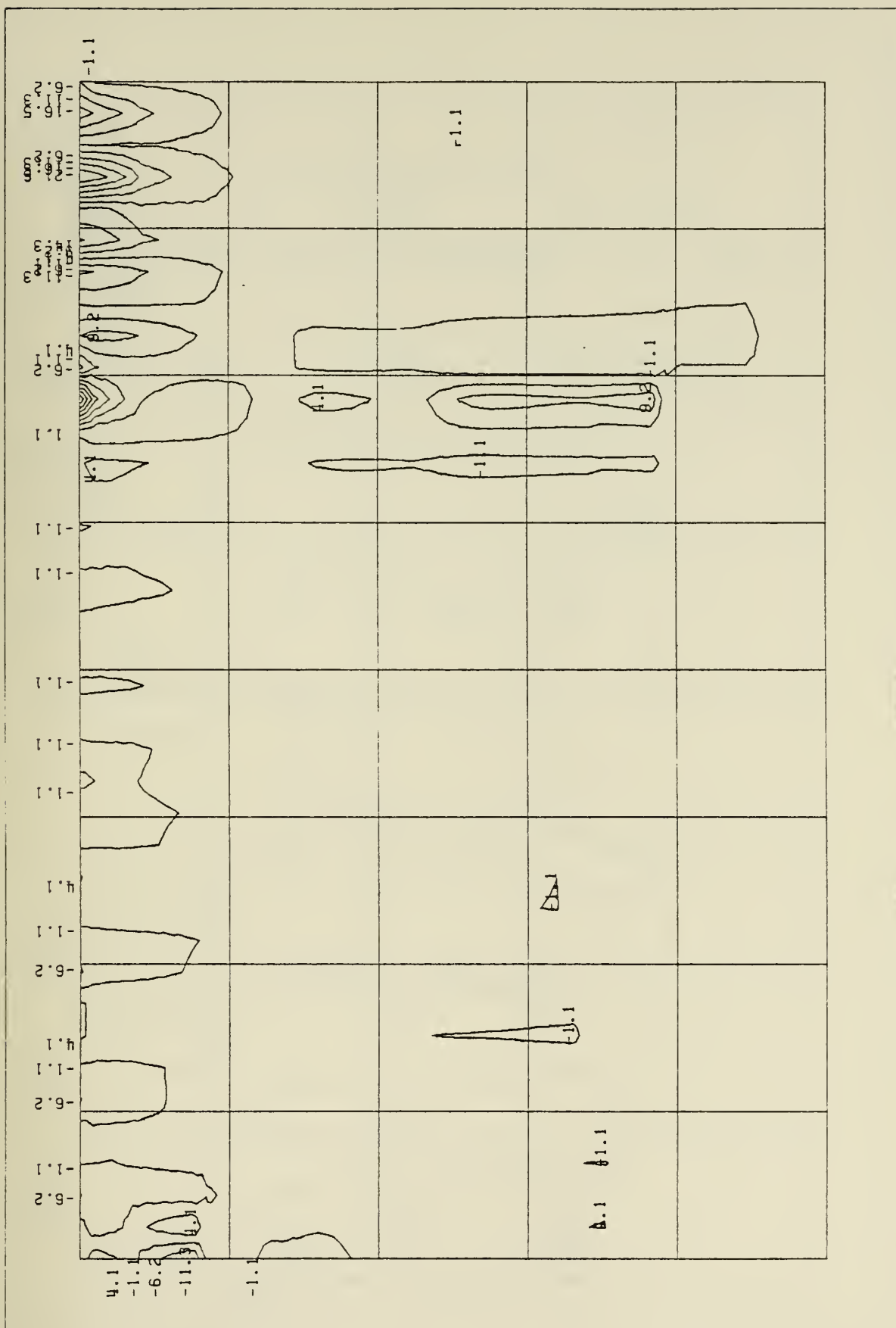


24°S SALT TRANSPORT

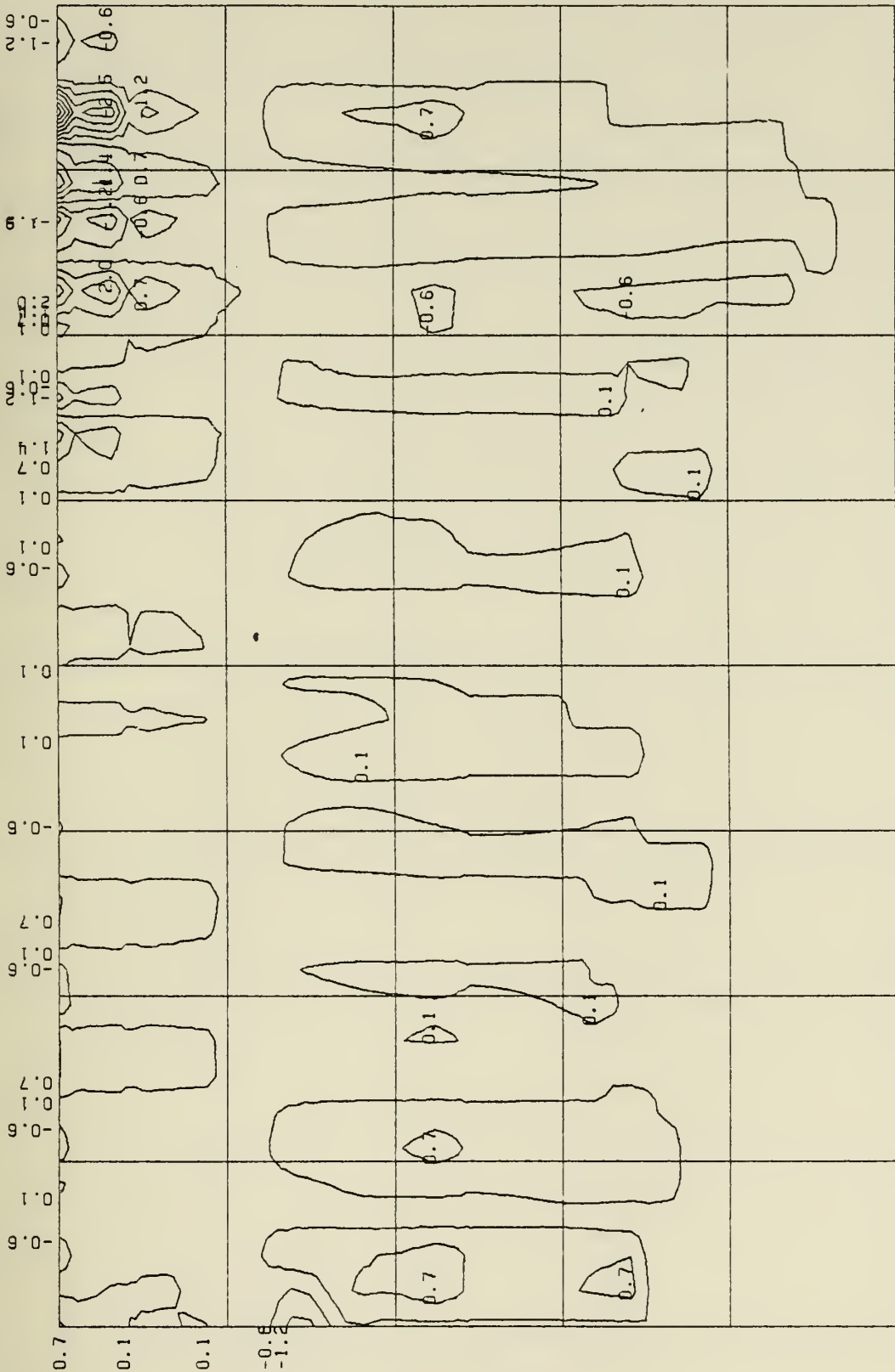
24°S SALT TRANSPORT

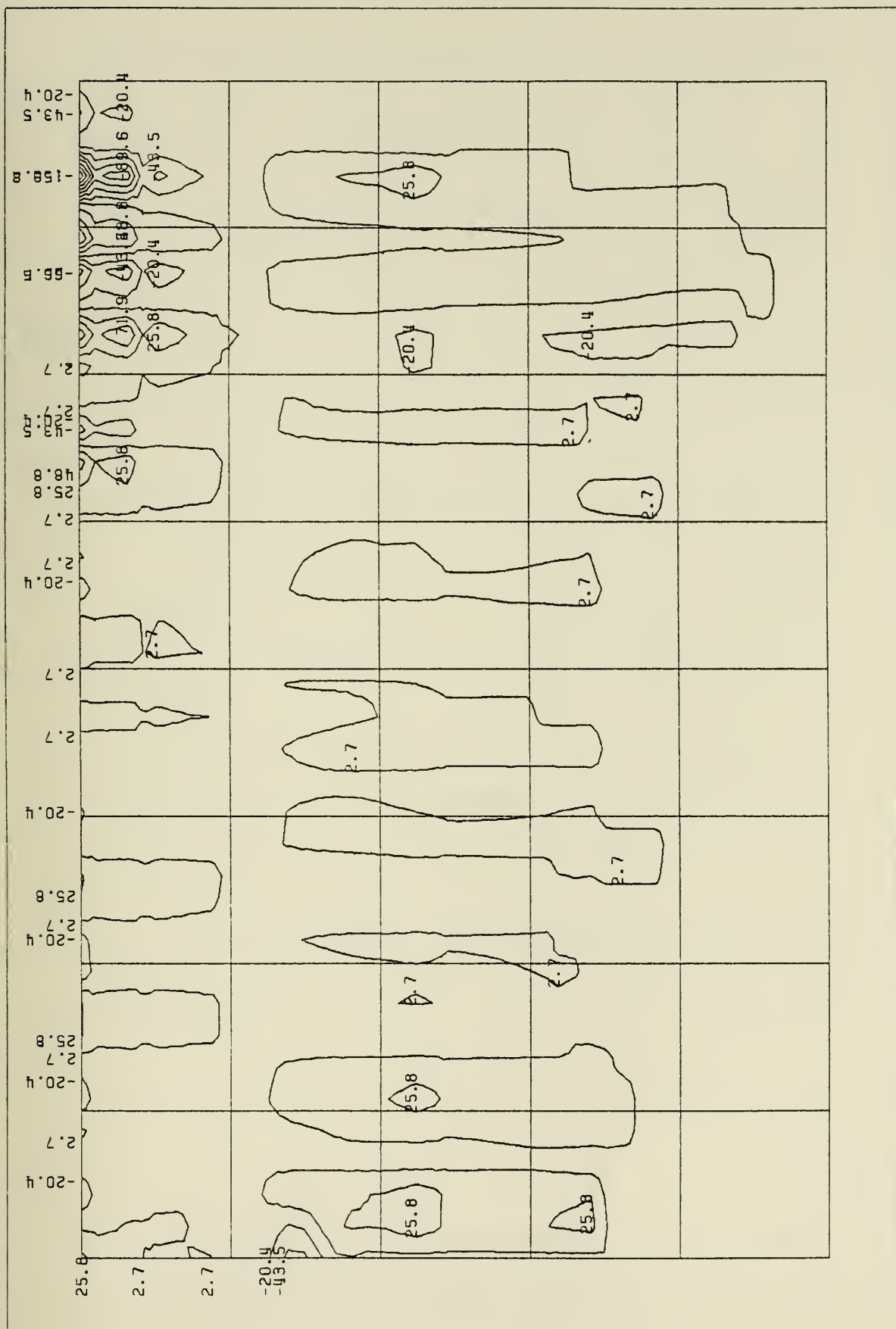


24° HEAT TRANSPORT



32° MASS TRANSPORT





32°S SALT TRANSPORT

APPENDIX C: COMPUTER PROGRAM

FORTRAN IV G LEVEL 21 MAIN DATE = 78326 15/02/25

```

0001 REAL *8 ITL(12), INFO(30,8)
0002 C IMENSION SQUARE(60)
0003 C IMENSION Z(48), VEL(48), R(4)
0004 C IMENSION IT(50), IS(50), S(50), IC(50)
0005 C IMENSION C(50), ST(48), SS(48), SGT(48), BDD(48)
0006 C IMENSION SGP(48), DH(48), BDH(48), SV(48), SVA(48)
0007 C IMENSION NPA(60), NP8(60), NO(60), NSTA(60,3), SLEV(60), BSVA(48)
0008 C IMENSION ALN(60), ANM(60), ICATE(60,3), DHT(60,48), ADH(48)
0009 C IMENSION XDENS(48,60), XSAL(48,60), XTEMP(48,60), YDE(48,60)
0010 C IMENSION YTT(48,60), YSL(48,60), TEMSUM(48), XMSUM(48), SSUM(48)
0011 5 FCFMAT(4F7.0)
0012 6 FCFMAT(15X, ' VELOCITIES COMPLETED ARE RELATIVE TO ', F5.0, ' METERS', )
0013 7 FCFMAT(1H1, ' VELOCITIES BETWEEN STATION ', 3A4, ' LATITUDE ', 12, F5.1,
0014 1, 'S LONGITUDE ', 13, F5.1, 'W DATE ', 3A4/24X, 'AND ', 3A4, ' LATITUDE ',
0015 2, 12, F5.1, 'S LONGITUDE ', 13, F5.1, 'W DATE ', 3A4//)
0016 8 FCFMAT(1H1, ' STATION ', 3A4, ' LATITUDE ', 12, F5.1, 'S LONGITUDE ',
0017 1, 13, F5.1, 'W DATE ', 3A4/5X, ' TO ', 3A4, ' LATITUDE ', 12, F5.1,
0018 2, 'S LONGITUDE ', 13, F5.1, 'W DATE ', 3A4//)
0019 9 FCFMAT(1X, 212, F5.0)
0020 10 FCFMAT(1H1, ' STATION ', 3A4, ' LATITUDE = ', 12, F5.1, 'S LONGITUDE =',
0021 1, 14, F5.1, 'W DATE ', 3A4//)
0022 12 FCFMAT(10X, '* INDICATES ADJUSTED VALUE')
0023 13 FCFMAT(14, 3A4, F3.0, 2, F5.1, F4.1, 3A4)
0024 15 FCFMAT(10X, 3, F5.2, 1, F10.3, 1, F8.2, 1, 8X, 4A8)
0025 16 FCFMAT(10X, ' DEPTH TEMPERATURE SALINITY SIGMA-T OXYGEN'//)
0026 17 FCFMAT(20X, ' OBSERVED VALUES'//)
0027 18 FCFMAT(7/20X, ' INTERPOLATED VALUES'//)
0028 19 FCFMAT(1CX, ' INTH TEMPERATURE SALINITY SIGMA-T SPEC VOL SPEC
0029 1, V ANOM MEAN SVA DELTA C DYNAMIC HEIGHT'//)
0030 20 FCFMAT(1CX, F5.0, F10.2, F12.3, F9.3, F11.4, F13.6, 23X, F12.5/70X, F11.6, F
0031 1, 11.5)
0032 21 FCFMAT(10X, F5.0, F10.2, 1, F11.3, 1, F8.3, F9.2, 1, 4X, 4A8//)
0033 DATA SD/0., 150., 300., 450., 500., 550., 660., 770., 880., 990., 1100.,
0034 1, 1210., 1300., 1430., 1540., 1650., 1760., 1870., 1980., 2090., 2200.,
0035 22, 2310., 2420., 2530., 2640., 2750., 2860., 2970., 3080., 3190., 3300.,
0036 33410., 3520., 3630., 3740., 3850., 3960., 4070., 4180., 4290., 4400.,
0037 44510., 4620., 4730., 4840., 4950., 5060., 5170.//
0038 DC 2000 I=1, 48
0039 XMSUM(I)=0.
0040 TEMSUM(I)=C.
0041 SSUM(I)=C.
0042 CCNT INUE
0043 CC 4 I=1, 48
0044 Z(I)=-SD(I)

```



```

0063 Y1(I,L)={XTEMP(I,L)+XTEMP(I+1,L))*0.5
0064 YSL(I,L)={XSAL(I,L)+XSAL(I+1,L))*0.5
0065 CCNT INUE
0066 NLT=ALT(L)
0067 NLA=ALN(L)
0068 WRITE (6,10) (NSTA(L,K),K=1,3),NLT,ALM(L),NLN,ANM(L),
0069 1(I(LATE(L,K),K=1,3)
0070 WRITE (6,17)
0071 WRITE (6,16)
0072 CC 29 I=1,NLV
29 WRITE (8,21) D(I),T(I),I(I),S(I),IS(I),SGP(I),C2(I),IO(I),
1(INFC(I,J),J=1,4)
0073 WRITE (8,12)
0074 WRITE (8,18)
0075 WRITE (8,15)
0076 NA=NA-1
0077 CF(I)=C.
0078 EC 30 I=1,NA
0079 BSVA(I)=(SVA(I)+SVA(I+1))*0.5
0080 CC(L,I)=BSVA(I)*(SD(I+1)-SD(I))
0081 CH(I+1)=CH(I)+CC(L,I)
0082 CC 31 I=1,NA
0083 DFT(L,I)=DH(I)
0084 1BSVA(I),CD(L,I)
I=NA+1
0085 CH(L,I)=DH(I)
0086 WRITE (8,20) SD(I),ST(I),SS(I),SGT(I),SV(I),SVA(I),DH(I)
0087 CCNT INUE
0088 IF (NGC-EC-0) GC TO 33
0089 DO 42 L=1,60
0090 IF (NPA(L)-EC-0) GO TO 3559
0091 BASE=SLEV(L)
0092 N1=NPA(L)
0093 N2=NPB(L)
0094 NL1=NU(N1)
0095 NU2=NG(N2)
0096 CC 43 I=1,NL1
0097 ACC(I)=DC(N1,I)
0098 DCF(I)=DFT(N1,I)
0099 DC 44 I=1,NL2
0100 BCC(I)=DC(N2,I)
0101 BCF(I)=DFT(N2,I)
0102 NLT=ALT(N1)
0103 NLN=ALN(N1)
0104 MLT=ALT(N2)
0105 MLN=ALN(N2)
0106 WRITE (6,8) (NSTA(N1,K),K=1,3),NLT,ALM(N1),NLN,ANM(N1),
1(I(LATE(N1,K),K=1,3), (NSTA(N2,K),K=1,3),MLT,ALM(N2),MLN,
2ANM(N2), (I(LATE(N2,K),K=1,3)

```



```

0108 ALAT=ALT(N1)+ALM(N1)/60.
0109 BLAT=ALT(N2)+ALM(N2)/60.
0110 IF (ALN(N1) .LT. 0.)GO TC 500
0111 ALCN=ALN(N1)+ANM(N1)/60.
0112 GC TC 502
0113
0114 500 ALCN=ALN(N1)-ANM(N1)/60
0115 502 IF (ALN(N2) .LT. 0.)GO TC 501
0116 BLCN=ALN(N2)+ANM(N2)/60.
0117 GC TC 503
0118 501 BLCN=ALN(N2)-ANM(N2)/60
0119 503 CALL DISTSTA (ALAT,ALON,BLAT,ELGN,X2,DIST)
0120
0121 1XMSUM,TEMSUM,SSUM,L,SQUARE,ACC)
0122 WRITE (6,7) (NSTA(N1,K),K=1,3),NLT,ALM(N1),NLN,ANM(N1),
0123 1(IICATE(N1,K),K=1,3),(NSTA(N2,K),K=1,3)
0124 2ANM(N2),(IICATE(N2,K),K=1,3)
0125 XS=(R(1)-R(2))/80.
0126 YS=(R(3)-R(4))/60.
0127 WRITE(6,100) XS,YS
0128 100 FORMAT( 15X,'X-SCALE:  "="'F4.1,' CM/SEC.//
0129 15X,'Y-SCALE:  "="'F5.2,' METERS.//)
0130
0131 42 CCNTINUE
0132 TSSUM=0.0
0133 THSUM=0.0
0134 THSUM=0.0
0135 WRITE (6,6002)
0136 FORMAT('1',20X,'DEPTH',1CX,'TOTAL MASS',10X,'TOTAL SALT',10X,'TOTAL
0137 LEAT',/35X,'TRANSPORT',11X,'TRANSPORT',11X,'TRANSPORT',)
0138 1 DC 5000 J=1,47
0139 TMSUM=TMSUM+XMSUM(J)
0140 THSUM=THSUM+TEMSUM(J)
0141 TSSUM=TSSUM+SSUM(J)
0142 WRITE (6,6003) J,SD(J),XMSUM(J),SSUM(J),TEMSUM(J)
0143 6003 FORMAT ( 10,'10X,14,6X,F5.0/25X,E16.6,4X,E16.6,4X,E16.6)
0144 CCNTINUE
0145 IX=48
0146 WRITE (6,6004) IX,SD(IX)
0147 WRITE (6,6004)
0148 6004 FCFORMAT ( 1,'37X,'-----',12X,'-----',12X,'-----')
0149
0150 7000 FCFORMAT('0',16X,'SUBTOTAL',)
0151 WRITE (6,6001) TMSUM,TSSUM,T+SUM
0152 6001 FORMAT ( 1,'25X,E16.6,4X,E16.6,4X,E16.6)
0153 WRITE(6,7001) XMSUM(48),SSUM(48),TEMSUM(48)
0154 7001 FCFORMAT (//14X,'BCYCLM AREA',5X,E16.6,4X,E16.6,4X,E16.6/13X,
0155 *CCNTINUE)

```


0149
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```

TMSUM=TMSUM+XMSUM(48)
TSSUM=TSSUM+SSUM(48)
TFSUM=THSUM+TEMSUM(48)
WRITE(6,6004)
WRITE(6,7002)
FORMAT('C',13X,'GRAND TOTAL')
7002 WRITE(6,6001) TMSUM,TSSUM,THSUM
33 STOP
END
```



```

0001 SUBROUTINE LGIP(N,V,M,SC,CV,NN)
0002 DIMENSION L(50),V(50),CV(48),SD(48)
0003 J=C
0004 CC=188 J=1,M
0005 LL=186 I=1,N
0006 IF(SD(J)-D(N))113,115,15C
0007 CV(J)=V(N)
0008 J=JJ+1
0009 GC TC 15C
0010 IF(SC(J)-D(1))114,114,116
0011 CV(J)=V(1)
0012 GC TC 17C
0013 IF(SC(J)-L(1+1))120,118,18C
0014 CV(J)=V(1+1)
0015 GC TO 17C
0016 IF(((D(1))-LT,SD(J)),AND,(SD(J),LT,D(2))),OR,GC TC 154
0017 ((D(N)-1),LT,SD(J)),AND,(SD(J),LT,D(N)))
0018 XA=(SD(J)-C(1))*((SD(J)-D(1+1))*V(I-1))
0019 1((D(I-1)-D(1))*((D(I-1)-C(1+1))*V(I))
0020 XB=(SD(J)-D(1-1))*((SD(J)-C(1+1))*V(I))
0021 XC=(SD(J)-C(1-1))*((SD(J)-C(1+1))*V(I+1))
0022 1((C(I+1)-D(1-1))*((D(I+1)-D(1))
0023 ANSU=XA+XB+XC
0024 YA=(SD(J)-D(1+1))*((SD(J)-D(1+2))*V(I))
0025 1((C(I)-D(1+1))*((D(I)-D(1+2))*V(I+1))
0026 YB=(SD(J)-C(1))*((SD(J)-C(1+2))*V(I+1))
0027 1((C(I+1)-D(1))*((D(I+1)-C(1+2))*V(I+2))
0028 YC=(SD(J)-C(1))*((SD(J)-C(1+1))*V(I+2))
0029 1((D(I+2)-D(1))*((D(I+2)-C(1+1))
0030 ANSD=YA+YB+YC
0031 CV(J)=(ANSU+ANSI)/2.
0032 GC TC 17C
0033 ZA=(SD(J)-D(1+1))*V(1)/(C(1)-D(1+1))
0034 ZB=(SD(J)-D(1))*V(1+1)/(C(1+1)-C(1))
0035 ANSL=ZA+ZB
0036 CV(J)=ANSL
0037 GC TC 17C
0038 CCNTINLE
0039 JJ=JJ+1
0040 CCNTINLE
0041 NN=JJJ
0042 RETURN
0043 ENC

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15/02/25

DATE = 78326

DSTIA

21

FORTRAN IV G LEVEL

```

0001 SUBROUTINE DSTIA (SATI,CNGI,SATII,ONGII,X2,DIST)
0002 IMPLICIT REAL*4 (K)
0003 REAL*8 A,E
0004 DATA A/111132.09/,B/566.05/,C/1.20/,D/.002/
0005 DATA E/1111415.12/,F/94.55/,G/.012/
0006 1J FORMAT (10X,'MEAN LATITUDE = ',F6.2/15X,'DISTANCE = ',F6.2,
0007 1, KILOMETERS.'/)
0008 CLN=2*3.1416/360
0009 AATII=SATII*CON
0010 $MERI=A-B*CCS(2*AATII)+C*CCS(4*AATII)-D*CCS(6*AATII)
0011 PARI=E*CCS(AATII)-F*CCS(2*AATII)+G*CCS(5*AATII)
0012 $MERII=A-B*CCS(2*AATII)+C*CCS(4*AATII)-D*CCS(6*AATII)
0013 PARII=E*CCS(AATII)-F*CCS(3*AATII)+G*CCS(5*AATII)
0014 ALLAT=($MERI+$MERII)/2
0015 ALLCN=($PARI+$PARII)/2
0016 CLAT=SATII-SATII
0017 DLGN=ONGI-CNGII
0018 KLAT=DLAT*ALLAT/1000
0019 KLGN=DLGN*ALLCN/1000
0020 KDIX=SQRT((KLAT**2+KLGN**2))
0021 DIST=KDIX
0022 WZ=1.458E-4
0023 PSI=(SATII+SATII)*0.5
0024 PSJ=(2.*3.14159/360.)*PSI
0025 SPSI=SIN(PSJ)
0026 IF (SPSI.LT.0.1) SPSI=0.1
0027 X2=1.0/(WZ*SPSI*KDIX)
0028 RETURN
0029 ENC
0030

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0001      SUBROUTINE SGTSVA (I,S,E,SGT,SV,SVA)
0002      ST=-((I+T-3)*.56)*2/503*(I+283.)/(I+67.26))
0003      SC=-0.093+0.6149*S-.000482*S**2+6.8E-6*S**3
0004      AT=T*(4.7867-.098185*T+.0010843*T**2)*1.E-3
0005      BT=T*(18.030-.8164*T+.01667*T**2)*1.E-6
0006      SGT=ST+(SU+.1324)*(I.-AT+BT*(SU-.4324))
0007      AFSI=1./((1.+SGT)*1.E-3)
0008      A=CAFSAI*1.E-9
0009      B=4680./(I.+1.*83E-5*(I))
0010      C=227.+28.33*I-.551*I**2+.004*I**3
0011      E=C*1.E-4
0012      G=(SC-28.)/10.
0013      H=147.3-2.72*I+.04*I**2
0014      U=105.5+9.5*I-.158*I**2
0015      V=1.5*U**2*I*1.E-8
0016      W=32.4-.87*I+.02*I**2
0017      X=4.5-.1*I
0018      Y=1.8-.06*I
0019      SV=AFSI-A*(B-C+E*U-V-G*(I-F*W)+G**2*(X-E*Y))
0020      AZ=.972643
0021      YA=-227.+0.61055*I
0022      YE=.01296*(147.3-.00324*I)
0023      YC=16.E-7*(4.5-D*.00018)
0024      AP=AZ-D*AZ*(B+YA-YB+YC)*1.E-9
0025      SVA=SV-AP
0026      RETURN
0027      END

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FCFTFRAN IV G LEVEL 21          GFOCLR          DATE = 78339          17/55/21

0001  SURCUINE  GECCUP  (HA,ACT,NB,BDH,SD,BASE,X2,VEL,NNN,DIST,
      1YCE,YTT,YSL,XMSUM,TFMSUM,SSUM,L,SQUARE,NGC)
0002  DIMENSION  X(48),Y(60),XL(48),YL(60),FL(48,60),WK(165)
0003  RCLAL *2  TITLE(12),TITL1(12),TITL2(12),TITL3(12)
0004  DIMENSION  ABVEL(43,60),CL(20),RMASS(48,60),BSALT(48,60),
      1RDEALT(48,60)
0005  LOGICAL *1  LTG(3)/.TRUE../.TRUE../
0006  DIMENSION  SQUARE(60)
0007  DIMENSION  APASS(48),ASALT(48),AHEATT(48),XMSUM(48),TFMSUM(48),
      1SSUM(48),YSL(48,60),YTT(48,60),AVDENS(48),AVTEMP(48),
      2AVSAL(48)
0008  DIMENSION  ADH(48),BDH(48),SD(48),RVFL(48),VFL(48),AM3(48),AVT(48)
0009  10 FCFMAT (12X,DEPTH DYN FT DYN HT DIFF HT REL VEL ABS V
      2 AVERAGE AVERAGE CM/SEC CM/SEC DENSITY TEM
      3 STA A SALINITY B-A TYPE./)
      4 FCFMAT (12X,F5.0,2X,3(F5.5,1X),2(F8.2,2X)/67X,F12.5,3X,F10.2,4X,F1
      5 10.2)
0010  12 FCFMAT (***** LEVEL OF NC ACTION MUST BE EQUAL TO A STANDARD DEPT
      16 ***** )
0012  14 FCFMAT (,10X,TOTAL VOLUME TRANSPORT IS COMPUTED BY SUMMING INCR
      2 FCFMAT TRANSPORTS ABOVE LEVEL CF NO MOTION: //5X,TOTAL TRANSPORT
      3 FCFMAT ICULAR TO THE PLANE CF THE STATIONS IS ,F7.3,' SVERCRPS
      4 RELATIVE TO ,F5.0,' METERS.)
0013  15 FCFMAT (//, * VALUES IN THIS COLUMN REPRESENT TRANSPORTS IN LAYER
      1 INCREMENTS //)
0014  16 FCFMAT (//12X,DEPTH,10X,ABS VOL,8X,ABS MASS,7X,ABS SALT,7X
      1,70S FLAT,15X,M,12X,TRANSPORT,6X,TRANSP(RT,6X,TRANSPORT,
      26X,TRANSPORT,8X,MASS,11X,SALT,11X,HEAT./)
0015  17 FCFMAT (12X,F5.0/22X,7(F16.5))
0016  18 FCFMAT (10,32X,*',14X,*',14X,*',20X,CUMULATIVE TOTALS
      1,.)
0017  19 FCFMAT (1,1) GC TC 50
0018  20 FCFMAT (Y=0.
      21 J=1,47
      22 X(J)=(SD(J)+SD(J+1))/2.
      23 XL(J)=50.
      24 CC J=1,47
      25 XL(J+1)=(1*110.)+50.
      26 CC 2001 I=1,48
      27 CC 2001 J=1,60

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BTSLT=0.0
CIRSLT=0.0
AINSLT=0.0
CEPSLT=0.0
SLESLT=0.0
SFCSLT=0.0
LNKSLT=0.0
ECTHT=0.0
CIRHT=0.0
AINHT=0.0
CENHT=0.0
DEPHHT=0.0
SUBHT=0.0
SFCHHT=0.0
LNKHH=0.0
IF(NA.LE.NB) GO TO 51
N=NB
GC TC 52
N=NA
51 DC 53 I=1,N
52 AMB(I)=BCH(I)-ADH(I)
53 RVEL(I)=AMB(I)*X2
54 I=1,48
54 IF(BASE.EQ.SD(I))GO TO 55
54 CCNT INUE
54 WRITE (6,12)
54 GC TC 70
54 NM=1
55 IF(NM.GT.N) NM=N
55 BASE=SD(NM)
55 I=1,N
55 VEL(I)=RVEL(NM)-RVEL(I)
56 ABVEL(I,L)=VEL(I)
  
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ABSVEL=VEL(N)
STMASS=0.0
STSALT=0.0
STHEAT=0.0
WRITE(6,10)
CC 600 I=2,N
J=1-1
AVGENS(J)=(YDE(J,L)+YDE(J,L+1))*0.5
AVSALT(J)=(YSLT(J,L)+YSLT(J,L+1))*0.5
AVTEMP(J)=(YTT(J,L)+YTT(J,L+1))*0.5
AVEL=(VEL(I)+VEL(J))*0.005
AVT(J)=AVEL*DIST*(SD(I)-SD(J))*1.0E-03
AMASS(J)=AVT(J)*AVGENS(J)
BMASS(J,L)=AVT(J)*AVGENS(J)
ASALTT(J,L)=AMASS(J)*AVSAL(J)
BSALTT(J,L)=AMASS(J)*AVSAL(J)
AHEATT(J,L)=AMASS(J)*AVTEMP(J)
BHEATT(J,L)=AMASS(J)*AVTEMP(J)
XMSUM(J)=XMSUM(J)+AMASS(J)
SSUM(J)=SSUM(J)+ASALTT(J)
TEMSUM(J)=TEMSUM(J)+AHEATT(J)
STMASS=STMASS+AMASS(J)
STSALT=STSALT+ASALTT(J)
STHEAT=STHEAT+AHEATT(J)
IF (I.LI.N) GC TO 141
XFAC=250000.
AVT(48)=ABSVEL*SQUARE(L)*XFAC/200.0E06
AMAST(48)=AVT(48)*AVGENS(N-1)
ASALTT(48)=AMAST(48)*AVSAL(N-1)
AHEATT(48)=AMAST(48)*AVTEMP(N-1)
XMSUM(48)=XMSUM(48)+AMAST(48)
SSUM(48)=SSUM(48)+ASALTT(48)
TEMSUM(48)=TEMSUM(48)+AHEATT(48)
STMASS=STMASS+AMAST(48)
STSALT=STSALT+ASALTT(48)
STHEAT=STHEAT+AHEATT(48)
IF ((AVTEMP(J) .LE. 273.0) .AND. ((34.65 .LE. AVSAL(J)) .AND.
141 IF ((AVSAL(J) .LE. 34.67)) .CC TC 4000
IF ((273.7 .LE. AVTEMP(J)) .AND. (AVTEMP(J) .LE. 277.4)) .ANE.

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0130 1((24.700 .LE. AVSAL(J)) .AND. (AVSAL(J).LE.34.975))) GC TO 4004
0131 1IF((275.87.LE. AVTEMP(J)) .AND. (AVTEMP(J) .LE. 280.0)) .AND.
1((33.80 .LE. AVSAL(J)) .AND. (AVSAL(J) .LE. 34.705))) GO TO 4002
0132 1IF((276.0 .LE. AVTEMP(J)) .AND. (AVTEMP(J) .LE. 291.0)) .AND.
1((24.45 .LE. AVSAL(J)) .AND. (AVSAL(J) .LE. 36.28))) GC TO 4003
0133 1IF((273.0 .LE. AVTEMP(J)) .AND. (AVTEMP(J) .LE. 275.5)) .AND.
1((24.68 .LE. AVSAL(J)) .AND. (AVSAL(J) .LE. 34.8))) GC TO 4004
0134 1IF((280.0 .LE. AVTEMP(J)) .AND. (AVTEMP(J) .LE. 282.0)) .AND.
1((24.10 .LE. AVSAL(J)) .AND. (AVSAL(J) .LE. 34.68))) GO TO 4005
0135 1IF(AVTEMP(J) .GE. 291.0) GO TO 4006
0136 1IF((272.0 .LE. AVTEMP(J)) .AND. (AVTEMP(J) .LE. 300.0)) .AND.
1((22.30 .LE. AVSAL(J)) .AND. (AVSAL(J) .LE. 37.00))) GO TO 4007
4000 1WRITE (6,11) SD(J),ADH(J),BDF(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
1AVTEMP(J),AVSAL(J)
1WRITE (6,30)
30 FORMAT ('+',10X,'A.A. BCTTCM')
BCIMAS =BCIMAS +AMASST(J)
BCIHT =BCIHT +AHEATT(J)
BCISLT =BCISLT +ASALTT(J)
BCIMAS=TBIMAS+AMASST(J)
BCIHT=TBHT+AHEATT(J)
BCISLT=TBISLT+ASALTT(J)
IF (1.0 .LT. N) GO TO 39
BCIMAS =BCIMAS +AMASST(48)
BCIHT =BCIHT +AHEATT(48)
BCISLT =BCISLT +ASALTT(48)
BCIMAS=TBIMAS+AMASST(48)
BCIHT=TBHT+AHEATT(48)
BCISLT=TBISLT+ASALTT(48)
GC TO 39
4001 1WRITE (6,11) SD(J),ADH(J),BDH(J),RVEL(J),VEL(J),AVDENS(J),
1AVTEMP(J),AVSAL(J)
1WRITE (6,31)
31 FORMAT ('+',10X,'A.A. CIRCUMPCLAR')

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0156 CIRMAS +AMASST(J)
0157 CIRHT +AHEATT(J)
0158 CIRSLT +ASALTT(J)
0159 TCRMAS=TCRMAS+AMASST(J)
0160 TCRHT=TCRHT+AHEATT(J)
0161 TCRSLT=TCRSLT+ASALTT(J)
0162 IF (I .LT. N) GO TO 39
0163 CIRMAS +AMASST(48)
0164 CIRHT +AHEATT(48)
0165 CIRSLT +ASALTT(48)
0166 TCRMAS=TCRMAS+AMASST(48)
0167 TCRHT=TCRHT+AHEATT(48)
0168 TCRSLT=TCRSLT+ASALTT(48)
0169 GO TO 39
0170 WRITE (6,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
32 JAVTEMP(J),AVSAL(J)
32 WRITE (6,32)
32 FCRMAT (I+,109X,'A.A. INTERMEDIATE.')
32 AINMAS +AMASST(J)
32 AINHT +AHEATT(J)
32 AINSLT +ASALTT(J)
32 TINMAS=TINMAS+AMASST(J)
32 TINHT=TINHT+AHEATT(J)
32 TINSLT=TINSLT+ASALTT(J)
32 IF (I .LT. N) GO TO 39
32 AINMAS +AMASST(48)
32 AINHT +AHEATT(48)
32 AINSLT +ASALTT(48)
32 TINMAS=TINMAS+AMASST(48)
32 TINHT=TINHT+AHEATT(48)
32 TINSLT=TINSLT+ASALTT(48)
32 GO TO 39
4003 WRITE (6,11) SD(J),ADH(J),BDH(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
33 JAVTEMP(J),AVSAL(J)
33 WRITE (6,33)
33 FCRMAT (I+,109X,'S. ATL. CENTRAL.')
33 CENMAS +AMASST(J)
33 CENHT +AHEATT(J)
33 CENSLT +ASALTT(J)

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0194 TCNMA5=TCNMA5+AMASST(J)
0195 TCNHT=TCNHT+AHEATT(J)
0196 TCNSLT=TCNSLT+ASALTT(J)
0197 IF (1.0,1.0) GO TO 39
0198 CENMAS =CENMAS +AMASST(48)
0199 CENHT =CENHT +AHEATT(48)
0200 CENSLT =CENSLT +ASALTT(48)
0201 TCNMA5=TCNMA5+AMASST(48)
0202 TCNHT=TCNHT+AHEATT(48)
0203 TCNSLT=TCNSLT+ASALTT(48)
0204 GO TO 39
4004 WRITE (6,11) SD(J),ADH(J),BDF(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
1AVTEMP(J),AVSAL(J)
34 WRITE (6,34)
FCRMAT (1,1,109X,'DEEP')
LEPMAS =DEPMAS +AMASST(J)
DEPHT =DEPHT +AHEATT(J)
DEPSLT =DEPSLT +ASALTT(J)
TCFMA5=TCFMA5+AMASST(J)
TCFHT=TCFHT+AHEATT(J)
TCPSLT=TCPSLT+ASALTT(J)
IF (1.0,1.0) GO TO 39
DEPMAS =DEPMAS +AMASST(48)
DEPHT =DEPHT +AHEATT(48)
DEPSLT =DEPSLT +ASALTT(48)
TCFMA5=TCFMA5+AMASST(48)
TCFHT=TCFHT+AHEATT(48)
TCPSLT=TCPSLT+ASALTT(48)
GO TO 39
4005 WRITE (6,11) SD(J),ADH(J),BDF(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
1AVTEMP(J),AVSAL(J)
35 WRITE (6,35)
FCRMAT (1,1,109X,'SUB ANTARCTIC')
SLEPMAS =SLEPMAS +AMASST(J)

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0225 SUBHT =SUBHT +AHEATT(J)
0226 SUBSLT =SUBSLT +ASALTT(J)
0227 TSEMAS=TSBMAS+AMASST(J)
0228 TSEHT=TSFHT+AHEATT(J)
0229 TSBSLT=TSFSLT+ASALTT(J)
0230 IF (I.LT.N) GO TO 39
0231 TBMAS =SUBHT +AMASST(48)
0232 TSEHT =SUBHT +AHEATT(48)
0233 TSBSLT =SUBSLT +ASALTT(48)
0234 TSEMAS=TSBMAS+AMASST(48)
0235 TSEHT=TSFHT+AHEATT(48)
0236 TSBSLT=TSFSLT+ASALTT(48)
0237 GO TO 39
0238 1 WRITE (6,11) SD(J),ADH(J),BDF(J),AMB(J),RVEL(J),VEL(J),AVDFAS(J),
4000 1 AVTEMP(J),AVSAL(J)
0239 30 FCRMAT (I,+,109X,'SURFACE')
0240 SFCMAS =SFCMAS +AMASST(J)
0241 SFCHT =SFCHT +AHEATT(J)
0242 SFCSLT =SFCSLT +ASALTT(J)
0243 TSEMAS=TSFMAS+AMASST(J)
0244 TSEHT=TSFHT+AHEATT(J)
0245 TSBSLT=TSFSLT+ASALTT(J)
0246 IF (I.LT.N) GO TO 39
0247 SFCMAS =SFCMAS +AMASST(48)
0248 SFCHT =SFCHT +AHEATT(48)
0249 SFCSLT =SFCSLT +ASALTT(48)
0250 TSEMAS=TSFMAS+AMASST(48)
0251 TSEHT=TSFHT+AHEATT(48)
0252 TSBSLT=TSFSLT+ASALTT(48)
0253 GO TO 39
0254 1 WRITE (6,11) SD(J),ADH(J),BDF(J),AMB(J),RVEL(J),VEL(J),AVDENS(J),
4007 1 AVTEMP(J),AVSAL(J)
0255 37 FCRMAT (I,+,109X,'UNKNCWN')
0256 UNKMAS =UNKMAS +AMASST(J)
0257 UNKHT =UNKHT +AHEATT(J)
0258 UNKSLT =UNKSLT +ASALTT(J)
0259 TLNMAS=TLNMAS+AMASST(J)

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0262 TUNHT=TUNHT+AHEATT(J)
0263 TUNSLT=TUNSLT+ASALTT(J)
0264 IF (I.LT.N) GO TO 39
0265 LNKMAS =LNKMAS +AMASST(48)
0266 LNKHT =LNKHT +AHEATT(48)
0267 UNKSLT =UNKSLT +ASALTT(48)
0268 TUNMAS=TUNMAS+AMASST(48)
0269 TUNHT=TUNHT+AHEATT(48)
0270 TUNSLT=TUNSLT+ASALTT(48)
0271 CONTINUE
0272 CONTINUE
0273 WRITE(6,11) SD(N),ADH(N),EDF(N),AMB(N),RVEL(N),VEL(N)
0274 NM=NM+1
0275 VT=0.
0276 DC 57 I=1,NM
0277 VT=VT+AVT(I)

C
C IF STATION B IS EAST OF STATION A, A NEGATIVE SIGN IN THE "ABS VEL"
C COLUMN IMPLIES A SOUTHWARD FLOWING CURRENT.
C

0278 WRITE (6,16)
0279 WRITE (6,18)
0280 N=N+1
0281 DC 62 I=1,N
0282 WRITE (6,17) SD(I),AVT(I),AMASST(I),ASALTT(I),AHEATT(I),XMSUM(I),S
1SLM(I),TEM SUM(I)
N=N+1
I=N
WRITE (6,17) SD(I),AVT(48),AMASST(48),ASALTT(48),AHEATT(48),XMSUM
*(48),SSUM(48),TEM SUM(48)
WRITE(6,1005)
1005 FORMAT(11X,'BOTTOM')
WRITE (6,1001)
1001 FORMAT (' ',41X,'-----',4X,'-----',4X,'-----',)

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